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THE IMPACTS OF VEHICLE CONTROL POLICIES ON THE SHORT RUN COSTS --ETC(U)

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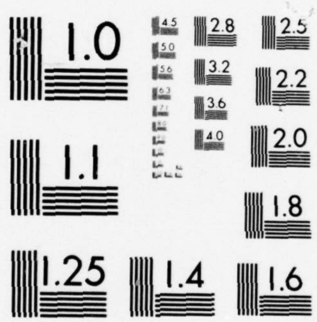

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THE IMPACTS OF VEHICLE CONTROL POLICIES
ON THE SHORT RUN COSTS OF CARRIERS:
STATE STREET TRANSITWAY,
A CASE STUDY

By

JOHN VINCENT MADDEN

APPROVED:

Mark A. Turnquist

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THE IMPACTS OF VEHICLE CONTROL POLICIES ON THE SHORT RUN COSTS OF CARRIERS: STATE STREET TRANSITWAY, A CASE STUDY.

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ABSTRACT

THE IMPACTS OF VEHICLE CONTROL POLICIES ON THE SHORT RUN COSTS OF CARRIERS: STATE STREET TRANSITWAY, A CASE STUDY

by

JOHN VINCENT MADDEN

A Thesis submitted to the Graduate School in partial fulfillment of the requirements for the degree of Master of Science in Transportation

This thesis investigates two vehicle control policies utilized to restrict delivery vehicles in the vicinity of downtown shopping malls. The two policies analyzed are complete vehicle prohibition from the mall, and time-restricted access to the mall by delivery vehicles. Under the time-restricted policy, delivery vehicles would be prohibited from entering the mall during the times of peak pedestrian and transit vehicle flow.

The impacts of these policies which are of prime concern to carriers relate directly to the increased time necessary to perform a given number of deliveries as a result of these policies. This reduced productivity results in an increase in the short run costs of the carriers. The proposed mall/transitway for State Street in Chicago was selected as a case study.

In order to measure the increased time it takes to make deliveries under the proposed vehicle control policies, a series

of queuing simulations were constructed. Two different methods of making a delivery were identified in the case study. They were the on-street or curb side deliveries, and the off-street or alley deliveries. The control policy that prohibits entry to the mall results in on-street deliveries being diverted to cross-street loading zones. The effects of this were simulated. The alley deliveries were simulated under the policy that prohibited entry to the mall, and under the policy that permitted them time-restricted entry and exit on State Street.

In almost all cases, the vehicle control policies result in increased costs to the carriers. Alternative ways to reduce these increased costs are discussed briefly, but not simulated.

Thesis Advisor: Mark Alan Turnquist
Assistant Professor
of Civil Engineering

ACKNOWLEDGEMENT

I wish to thank the thesis committee members, Drs. Andrew F. Daughety, Mark A. Turnquist, and Patrick M. O'Sullivan for the time and effort they invested in me during the research and writing of this thesis. Their help is much appreciated.

Mr. Ted Anastos of the Chicago Cartage Exchange contributed data on the operating costs of carriers in the region, as well as a very useful discussion on their operations. The staff of the Transportation Center and the Transportation Center Library were supportive to the highest degree whenever I needed their assistance. The funding for my education here was provided through a fellowship from the U.S. Army. For all of this assistance I am grateful.

Most of all, I am indebted to my thesis advisor, Mark Turnquist, for his technical and philosophical guidance, without which the learning experience would have been far less than it was.

Any errors contained herein are, of course, my responsibility.

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Chapter 1

INTRODUCTION AND BACKGROUND

1.1 Introduction

Most studies of the movement of urban goods have investigated policies to reduce the perceived social costs of truck operation. Less attention has been given to the costs to the carriers if these policies were implemented. The construction of downtown shopping malls in the retail districts of central cities requires the use of vehicle control policies. Two of these policies are complete vehicle prohibition from the mall, and time-restricted access to the mall by delivery vehicles. The proposed mall/transitway for State Street in Chicago was selected as a case study to measure the costs to carriers if these policies were introduced. A surrogate for measurement of these costs is the extent of the increase in time necessary to perform deliveries under these policies. This increase was obtained from a series of queuing simulations of the delivery operations.

1.2 Previous Studies and Proposals

The pick up and delivery operation (PUD) is a facet of urban goods movement (UGM) which involves the collection

of goods from several origins in the metropolitan region for delivery to a terminal for line haul, or the distribution of goods from the line haul terminal to numerous destinations in the urban area. In some cases, the PUD vehicle may perform the line haul function as well.

A study done by Wilbur Smith and Associates (31) in 1969 was the first serious look at PUD operation. This and most subsequent studies were from the viewpoint of a public policy planner who was still amassing data, and speculating upon possible government imposed programs to alleviate perceived industry problems. Many of these programs have centered around implementation of a consolidation concept [see, for example, Parsons (4)] or a nighttime delivery program such as Project Moondrop in London (25). The principal concern to date has been for the reduction of perceived social costs of truck operation such as congestion effects upon auto movement, noise pollution, and aesthetic pollution. The costs to the carriers if the proposed policies were introduced has received much less attention.

1.3 Downtown Shopping Malls and Urban Goods Movement

An increasingly common public project that will have an effect upon the costs of the carriers is the construction of downtown shopping malls. The retail centers of many of the cities in this country are undergoing

stagnation or a decline in sales revenue. In an attempt to halt and reverse this trend, some cities have proposed that the streets of their retail centers be closed to private vehicular traffic and returned to pedestrian use. Provision of pedestrian amenities in these traffic-free environments is intended to attract some of the suburban sales dollars back to the downtown, and spur investment in the central city. In some cases, bus or light rail transit is permitted to remain within a right of way on the mall.

Coincident with provision of an attractive, traffic-free environment for the pedestrian, however, is the necessity of continuing to provide goods delivery to the retail establishments in the vicinity of the mall. Several vehicle control policies have been proposed to maintain the pedestrian environment as much as possible, yet accomplish the necessary deliveries. One of these policies involves complete vehicle prohibition from the mall. This would have the greatest effect upon vehicles which provide on-street deliveries to merchants, either directly across the curb to the retailer's front door or through a service elevator, delivery chute, or stairwell within the sidewalk itself. These vehicles would be forced to park on side or cross streets and carry or hand truck goods some distance. This policy would not seem to have a great impact upon vehicles that deliver to retailers through a

grade-separated service tunnel beneath, unless the entry point to either of these is from the street that is to be designated as the mall. An example where an extensive alleyway system, many off-street loading doors/docks, and few curb-side deliveries permitted successful implementation of this policy of complete vehicle prohibition is the Nicollet Mall in Minneapolis (1) (22) (40).

A second, less extreme policy is one of time-restricted access to the mall by delivery vehicles. Carriers making curb side deliveries to buildings without off-street facilities would be permitted entry to the mall only during specified hours. Vehicles that must enter an alley from the mall to make a delivery to a building's loading door or recessed loading dock will be permitted access across the mall during these hours as well. Obviously, this second policy is less desirable from the point of view of preserving the pedestrian environment. The nature of the downtown of many older cities is such that their narrow alleyways and few off-street facilities preclude complete vehicle prohibition from the mall. In newer cities, with ordinances requiring off-street facilities in all new construction, this policy may not be as severe. Copenhagen's Strøget is an example of operation under a policy of time-restricted access (19).

The use of either of these policies, or variations of them, depends upon the unique physical characteristics of the retail center of the city under consideration. As discussed above, the implementation of either of them will have an effect upon the carriers serving the area. In an attempt to show these effects in terms of the increased time it takes to make deliveries, and hence, the increase in short run marginal costs to the carriers, a case study was selected. This case study is the proposed mall/transitway for State Street in Chicago.

1.4 The Case Study Area

State Street is the major downtown retail district of Chicago, with over $600 million in retail sales annually (31). The construction of a mall/transitway on this street has several objectives, including the improvement of public transportation services to and within the downtown area, the enhancement of the pedestrian environment on State Street, and the stimulation of the economy of the central area.

The transitway is to extend nine city blocks along State Street, from Wacker Drive on the north to Congress Parkway on the south. The location of the project in relation to the rest of the downtown area is shown in figure 1.1. The existing roadway of six lanes will be narrowed to two exclusive bus lanes, with boarding bays at the end

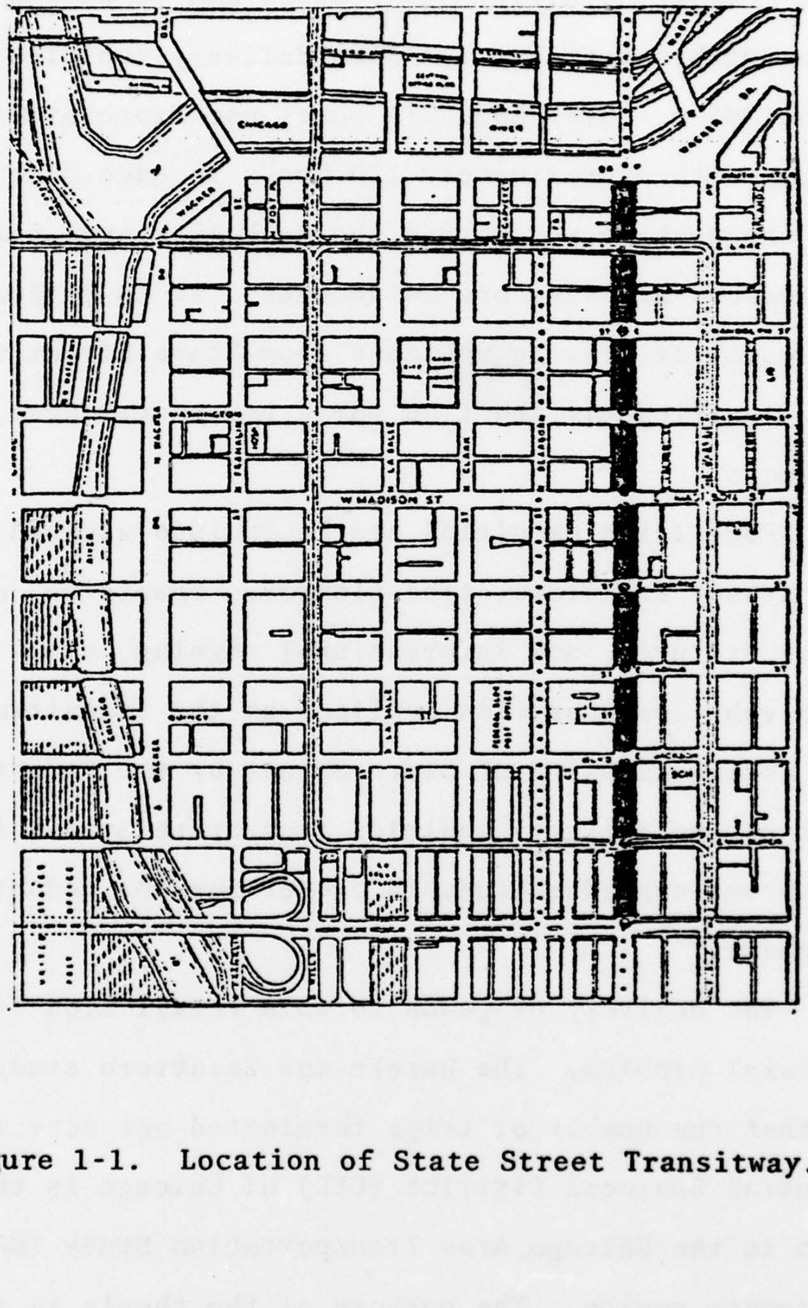

Figure 1-1. Location of State Street Transitway.

of each block. Cross streets will remain open to general traffic. The use of the two lanes is to be restricted to Chicago Transit Authority (CTA) buses and to emergency vehicles with exceptions for some delivery vehicles to be noted later. Over 2600 CTA buses use State Street each day, with approximately 120 buses in each direction during the peak hour. During the peak 15 minute period, scheduled bus headways are 20 seconds. It is anticipated that removal of private vehicles from State Street will reduce significantly the time for a bus to traverse these nine blocks.

Pedestrian amenities are to include widened sidewalks, street furniture, tree planters, fountains, new lighting fixtures, new informational signing, etc. The reduced vehicle/pedestrian conflict on the transitway will permit easier crossing of State Street by the pedestrian. Removal of the delivery vehicles from State Street is one of the prime considerations in preserving the pedestrian environment.

The delivery of goods to this retail area is a non-trivial problem. The Warnke and Zavattero study (42) shows that the number of trips terminated per acre for the Central Business District (CBD) of Chicago is the highest in the Chicago Area Transportation Study (CATS) eight-county region. The purpose of the thesis is to identify the immediate impacts of the transitway project

upon the delivery costs of the carriers serving the State Street retail area.

Two different types of deliveries need to be distinguished from one another. These are the on-street or curb-side deliveries, and the off-street or alleyway deliveries. Closure of State Street to delivery vehicles, will affect each type of delivery in a different way.

The curb-side deliveries will be diverted to loading zones on the cross streets. The Chicago Department of Public Works (DPW) study (26) recorded data on curb-side deliveries on the east and west sides of State Street for the central seven of the nine blocks that comprise the mall. The deliveries for the northern-most and the southern-most blocks were not tabulated due to the insignificant number involved or the marginal retail nature of the block. The number observed on the west curb of State Street was approximately four times the number observed on the east curb. This is due primarily to the poorer alleyway system serving the blocks west of State Street.

In general, the alleys east of State Street are wider and run north and south; the alleys west of State are narrow, and run east and west. Closure of State is not likely to have a severe impact upon the alley deliveries to the east of State, due to the north-south orientation of the alleys and the fact that the cross streets will remain open. In addition, the fewer curb-side

deliveries on the east side of State can be diverted to these alleys. The DPW also recorded the numbers of vehicles entering the alleys from State. All of these serve the blocks west of State. Again, the northern-most block was not recorded, due to the insignificant number of vehicles involved. The study area for purposes of this thesis is thus redefined to encompass the blocks and alleys west of State, between Lake on the north and Van Buren on the south.

1.5 Outline of the Thesis

As discussed in the introduction, the purpose of this thesis is to measure the costs to the carriers if the proposed vehicle control policies were introduced. Chapter 2 discusses how the increased time to make a delivery under these policies will be converted to a dollar value through the use of labor cost figures. The theory behind the construction of the queuing model to measure the increased time is discussed in Chapter 3. Chapter 4 describes the analysis that is necessary to determine confidence intervals about estimates of the mean wait time in the queue. These estimates are obtained from the queuing simulations. The detailed discussion of the models for the on-street deliveries and the results of those simulations are contained in Chapter 5. Similar information on the off-street deliveries is contained in Chapter 6 for

each individual alley. Chapter 7 briefly discusses some alternative policy and facility changes that could serve to reduce the magnitude of the increased costs observed in the simulation results. Chapter 8 contains the summary and conclusion. An explanation of the notation used in the discussions of the queuing theory and the statistical analysis is in Appendix A. The simulation programs are in Appendix B.

Chapter 2

OPERATING COSTS OF THE CARRIERS

2.1 Introduction

The increased time to make a delivery in the mall area is reflected as an increase in the carrier's immediate short run marginal costs. This increased time is converted to a dollar value through use of labor cost figures.

2.2 Cost Characteristics of the Carriers

The objective of this thesis is to ascertain the effects on the costs of PUD carriers resulting from imposition of several different operating policies for deliveries to the State Street transitway.

What is occurring in the State Street area, is a shift upward of the carrier's Short Run Marginal Cost (SRMC) curve in figure 2-1 caused by a change in the productivity of the factors of production, the vehicle and drivers. The present number of deliveries made by a carrier is Q_1. The imposition of a vehicle control policy will cause an increase in the cost to make these deliveries, and the SRMC curve will shift upward to SRMC'. The magnitude of this shift is the difference between P_3 and P_1. The

difference in time to make a delivery is measurable, and its dollar value can be found. If the function that describes the shape of the SRMC curve were also known, the quantity Q_3 that the carrier should deliver under the new conditions could be found. This thesis does not attempt the latter; what it does show is the magnitude of the increase, from P_1 to P_3, of the carrier's short run marginal cost at the present number of deliveries made by the carriers.

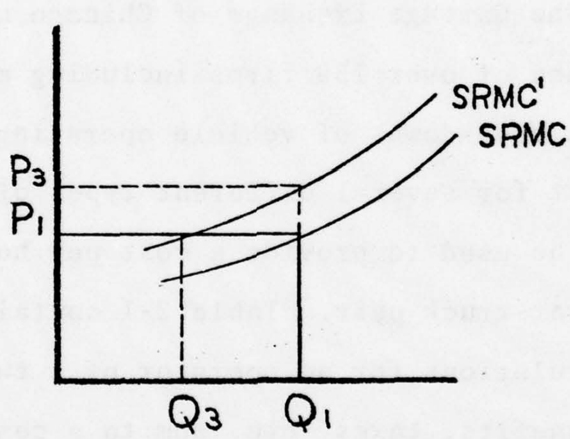

Figure 2-1. Carrier's Short Run Marginal Costs

2.3 The Carrier's Expenses

The inputs to the simplified production function for the carrier are the number of truck-hours and the number of man-hours. It takes an amount of truck-hours and an amount of man-hours to produce one delivery. Under

the vehicle control policies, the amount of man-hours and the amount of truck-hours to make one delivery is increased. The true cost function would include, among others, both the truck and man-hour inputs. An approximation to this will use just the time input. In order for the carrier to produce the same number of deliveries in the State Street area and elsewhere he may service in the city, he will have to increase his total fleet size. This added capital expenditure is not accounted for in the analysis.

The Cartage Exchange of Chicago maintains, from a data base of over 150 firms including more than 6000 vehicles, breakdowns of vehicle operating expenses and labor cost for several different types of trucks. This data can be used to provide a cost per hour for operation of a driver-truck pair. Table 2-1 contains gross labor cost calculations for an operator of a two axle truck. Wages, benefits, taxes, etc. sum to a cost per hour figure for a driver of \$13.68 in column 1. Time and a half for overtime, and double time are shown in columns 2 and 3, respectively. The straight time cost is \$547.28 for a 40 hour work week. The 40 hour assumption is valid, since union rules (7) (17) require that an operator, once called, be paid for the entire week.

Table 2-2 contains an analysis of vehicle operating expenses for a 20', 24000 lb. gross weight truck. The capital investment, interest expense, other fixed expenses,

Table 2-1

GROSS LABOR COST FOR A TWO AXLE TRUCK

No. of Holidays	9
Average Vacation Days	15
Average Misc. Off Days	6
Total Off Days in Year	30
Straight Time Hours in Day	8
Total Idle Hours in Year	240
No. of Weeks in Year	52
Straight Time Hours in Week	40
Gross Straight Time Hours in Year	2080
Total Idle Hours in Year	240
Actual Straight Time Hours Worked in Year	1840

WAGE TAXES AND INSURANCE

Item	%	Limits	Cost/Year
F.I.C.A.	.0585	15300.00	895.05
State Unemployment Insurance	.0270	4200.00	113.40
Federal Unemployment Insurance	.0058	4200.00	24.36
Workmens Compensation Insurance Manual Rate	.0531	Gross Wages	
Total Wage Tax and Insurance			1032.81

Table 2-1 (continued)

GROSS LABOR COST

Item	Straight Time	Overtime	Extra Man Overtime
Base Hourly Rate 7.18 + .65	7.8300	11.7450	15.6600
Cost of Living Increase NONE IN 1976			
Sub Total "A"	7.8300	11.7450	15.6600
Holiday Cost 8 x 9 x 7.83 = 563.76 ÷ 1840	.3064		
Vacation Cost 10 x 15 x 8.62 = 1293.00 ÷ 1840	.7027		
Misc. Off Day Cost 6 x 8 x 7.83 = 375.84 ÷ 1840	.2043		
Bonus Cost			
Sub Total "B"	9.0434	11.7450	15.6600
Wage Tax and Insurance 1032.81 + 1840	.5613		
Health, Welfare and Pension 52.00 x 52 = 2704.00 ÷ 1840	1.4696		
Bonding Cost	.0100		
Chicago Head Tax 36.00 ÷ 1840	.0195		
Workman's Comp. .0531 x B	.4802	.4802	4802
Safety Program and Awards 45.00 ÷ 1840	.0244		
Physical/Security Checks 75.00 ÷ 1840	.0407		
Sub Total "C"	11.6491	12.2252	16.1402

Table 2-1 (continued)

Gross Labor Cost (continued)

Item	Straight Time	Overtime	Extra Man Overtime
Payroll Handling 2%	.2330	.2445	.3228
Sub Total "D"	11.8821	12.4697	16.4630
Engineering Fee 2%	.2376	.2494	.3293
Sub Total "E"	12.1197	12.7191	16.7923
General Overhead and Supervision 9½%	1.1514	1.2083	1.5953
GROSS LABOR RATE PER HOUR	13.2711	13.9274	18.3876
BI/PD Ins 2½% CARGO Ins ½%	.4110	.4307	.5687
TOTAL	13.6821	14.3581	18.9563

Source: Cartage Exchange of Chicago

Table 2-2

VEHICLE OPERATING EXPENSES

Vehicle Cost	
Total Investment[1]	13000.00
Tire & Tube Cost	1138.92
Investment Less Tire & Tube Cost	11861.08
Residual Value 10%	1186.11
Amount to be Depreciated (5 years)	10674.97

Variable Expense Per Mile	
Gasoline .56/gal. (5 MPG)	.1120
Oil	.0012
Greasing	.0006
Tires & Tubes	.0220
Maintenance & Repair	.1100
Sub Total "A"	.2458
Overhead 15%	.0369
Sub Total "B"	.2827
Contingency Per Mile	+.0023
Variable Cost Per Mile	.2850

[1]Referred to in this table as L1.

Table 2-2 (continued)

Annual Fixed Expense	
Depreciation	2134.99
Interest on Total Investment 8¼ L1	1040.00
State License	330.00
City Vehicle Tax	85.00
Federal Use Tax	--
State Commerce Commission Tax	5.00
Personal Property Tax 1½% of L1	195.00
Other Taxes	--
Safety Inspection	10.00
BI & PD Insurance See Contingency/Week	--
Collision Insurance 2% of L1	260.00
Collision Reserve	250.00
Fire & Theft Insurance .006% of L1	78.00
Cargo Insurance See Contingency/Week	--
Washing $6.50 x 52	338.00
Re-Painting & Lettering 1% of L1	130.00
Garage Rent or Proration $15.00 per week	780.00
Anti-Freeze & Safety Equipment 1% of L1	130.00
Accessories	100.00
Other Expense	--
Sub Total "A"	5865.99
Overhead 15%	879.90

Table 2-2 (continued)

Annual Fixed Expense (continued)		
Sub Total "B"		6745.89
Engineering Fee	2%	134.92
Sub Total "C"		6880.81
Profit	10%	688.08
Total Annual Fixed Expense		7568.89
Fixed Expense Per Week		145.56
Contingency Per Week	3%	4.37
Standby Charge Per Week		150.93

Source: Cartage Exchange of Chicago

and assumptions as to service life produce a fixed cost per week of $150.93. Fuel, maintenance, etc. yield a variable cost per mile of $0.285. An assumption, from experience, of 250 miles per week, produces a variable cost per week of $71.25. A reduction in the number of deliveries by carriers may reduce the number of miles driven. Unless this change is radical, the percentage change in the total cost will be small.

The sum of labor cost per week, capital cost per week, and variable vehicle operating costs per week totals $769.46. The fixed costs contained herein are predicated upon an assumption of a 40 hour work week. It would be improper to allocate these to the increased time it takes to make deliveries over present. The labor input cost is over 70% of total cost in a 40 hour week. As an approximation, the $13.68 cost of a man-hour input is used to show the cost to the carriers of increased time observed under different operating policies.

Chapter 3

THE QUEUING MODEL

3.1 Introduction

Queuing models were constructed for the on- and off-street deliveries. This was done to show the increase in wait time resulting from congestion under the proposed vehicle control policies. Information on arrivals was taken from the DPW study (26) and a Poisson arrival pattern was assumed. Gamma distributions were used for service times, with the mean from (26). The shape of the distributionused was that from an area of similar land use, as observed in the PINY study (9). An attempt at an analytic solution was terminated, as it rapidly became too complex. The models were simulated using GPSS (General Purpose Simulation System).

3.2 Arrival Data

The arrival of vehicles for both the on- and off-street delivery processes will be modeled by a Poisson arrival pattern. The use of an exponential distribution for inter-arrival times is predicated upon the assumption that the arrivals are completely random. The probability of an arrival during any given interval of time, then,

is proportional to the length of that arrival, and is independent of the previous pattern of arrivals. There are significant peaking characteristics during the day, so an assumption of constant arrival rates will not suffice. To reflect the time-variant nature of λ the day was divided into several different time periods, and a separate λ was calculated for each time period and for each block.

The arrival data collected in the DPW study for curb-side deliveries was not in a form which was readily usable in a queuing model. The accumulation of delivery vehicles on State was recorded at fixed time intervals instead of recording the time of arrivals of those vehicles. In order to derive the mean arrival rate λ from this information, it was necessary to manipulate the data in the following way.

On a block face there is space for 10 delivery/service vehicles. This can be treated as a 10 channel service facility. Since L, the number of vehicles in the system is always less than 10 (see Table 5-1), at no time on any block are all the servers in use. Thus, it is reasonable to model the system as one in which no queue forms. In the case of Poisson arrivals where no queue forms, the mean number of vehicles observed in the system is independent of the type of service distribution used [(24) pp. 45-47]. For the no-queue case of a multiple channel service facility with a Poisson arrival

pattern, the mean number of vehicles in the system is given by [(24) p. 31]

$$L = \begin{cases} M - (1/\rho) & (\rho >> 1) \\ \rho M & (\rho << 1) \end{cases} \qquad (3.1)$$

For the data from the curb-side deliveries, the utilization factor ρ for the whole system is very much less than one, thus the second relation is assumed to hold. For the multiple channel case, ρ is defined by

$$\rho = \lambda / (M\mu) \qquad (3.2)$$

Substituting for ρ in equation (3.1) above and rearranging will yield the arrival rate λ for the curb-side deliveries.

The data collected by the DPW for the curb-side deliveries was only for the hours from 0800 to 1500.[1] The actual close of the delivery day, as used in the model was 1600. The arrival rate for 1500 was extended to 1600. It was assumed that no deliveries were made after 1600, so the arrival rate was reduced to zero after this hour.

3.3 Service Data

The Chicago DPW has collected some basic data on the delivery times in the State Street area (26). An estimate of dwell times for on-street deliveries was obtained

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[1]The 24 hour military clock system is used, e.g. 0800 = 8 A.M., 1500 = 3 P.M.

through a parking survey. An estimate of the duration of alley deliveries was obtained through a merchants survey. This latter method was inexact for two reasons. First, it relied upon the retailers' perceptions of the delivery times and not on recorded delivery times. Second, the time increments used on the survey forms presented to the merchants were large and only provide a coarse approximation of the average time. For neither the curb-side nor alleyway deliveries was the distribution of delivery times observed; only an estimate of the mean dwell time for each was obtained.

A study (9) by the Polytechnic Institute of New York (PINY), of goods delivery in Brooklyn recorded dwell time data for individual deliveries. This data was classified by land use of the delivery point, and, depending upon the land use, by parking mode (legal or illegal) and type of delivery (curb or dock) as well. This data was fitted to a gamma distribution having different parameters for the classifications noted.

The data obtained by the DPW for the mean dwell times cannot be used alone to describe the service time distribution unless the wholly unrealistic assumption is made that service times are constant. While cognizant of the dangers involved, the decision was made to take the gamma service distribution as observed in the PINY study and, while retaining the shape, rescale it with the mean

service times of the DPW study. As some estimate of the distribution of service times is necessary for the queuing model, it was felt that the distribution of observations at land uses similar to State Street would be acceptable.

The gamma distribution is defined by two parameters, α and β, termed the "shape" and "scale" parameters, respectively. The mean of the distribution, T_s, is given by

$$T_s = \alpha\beta \tag{3.3}$$

and the variance is

$$Var = \alpha\beta^2 \tag{3.4}$$

The shape parameters of the gamma distributions used in the PINY study (9) were $\alpha = 1.25$ for the on-street deliv ries, and $\alpha = 1.50$ for off-street deliveries. The mean service times obtained from the DPW study (26) were $T_s = 22$ minutes for the curb-side deliveries, and $T_s = 30$ minutes for the alleyway deliveries.

The diversion of an on-street delivery to a cross-street loading zone will increase the dwell time of that vehicle at the curb, since the driver will now have to walk up to half a block to bring the goods to the retailer. With the length of a block, and an average walking speed known, the dwell time for a cross-street delivery was assumed to be $T_s = 24$ minutes.

Substituting the information on the shape parameter (from the PINY study) and the mean service time for each method of delivery (from the Chicago data) in equation (3.3) produces values for the scale parameter β shown in Table 3-1.

Table 3-1

Service Distribution Parameters

Type of Delivery	T_S	α	β
curb	22	1.25	17.6
cross-street	24	1.25	19.2
alley	30	1.50	20.0

3.4 Attempts at Analytic Solution

Initially, an attempt was made to find an analytic solution to the queuing problem for the curb-side deliveries diverted to cross-street loading zones. The gamma service distribution from the PINY study (9) had a shape parameter of α = 1.25 for the on-street deliveries. As the calculations for a gamma distribution with a non-integer α are quite tedious, approximations of α = 1 (exponential) and α = 2 (Erlang-2) were used, in an attempt to bound the solution for the true gamma distribution.

The attempt was not successful, as it would have required the exceedingly complex calculation of the

transient solutions. This would have been necessary because the arrival rates increased to a value much greater than the service rates. As a rigorous discussion of transient solutions of multiple channel servers with infinite queues is beyond the scope of this thesis, a decision was made to terminate any further attempts at an analytic solution, and construct a simulation model instead.

The simulation language chosen to model the queuing systems discussed above was GPSS (General Purpose Simulation System). This decision was made based upon the availability of the compiler at Northwestern University's Vogelback Computing Center, its suitability for the queuing systems under discussion, and the author's familiarity with the language.

Chapter 4

STATISTICAL ACCURACY OF THE RESULTS

4.1 Introduction

The previous chapter has discussed the theory behind the construction of the queuing models for the on- and off-street deliveries. The details of the individual models are discussed in subsequent chapters. A primary output of these models is the mean wait time in the queue to make a delivery. This chapter describes the analysis necessary to determine confidence intervals about estimates of this value. The fact that successive observations of wait time within a given simulation run are auto-correlated must be accounted for. The result of this analysis is a determination of the number of experimental replications which must be conducted in order to attain the required confidence in the model results.

4.2 Calculation of Confidence Intervals

During a simulation run, n observations of waiting time W_j, are obtained. The mean of these observations, $\overline{X}$, is given by,

$$\overline{X} = \frac{1}{n} \sum_{j=1}^{n} W_j \tag{4.1}$$

The sample mean $\overline{X}$ is an unbiased estimator of the true mean wait time, μ_X. If each W_j is independent, the variance of the sample mean, $V(\overline{X})$, is related to the true variance V(X) as follows:

$$V(\overline{X}) = \frac{V(X)}{n} \tag{4.2}$$

It can also be shown that an unbiased estimate of the true variance is given by,

$$s^2 = \sum_{j=1}^{n} \frac{W_j{}^2 - n\overline{X}^2}{n-1} \tag{4.3}$$

With an estimate, $\overline{X}$, of the true mean, and V(X), the true variance of X, it is possible to obtain a confidence interval about the true mean. For large n (n > 30), the central limit theorem applies, and the distribution of $\overline{X}$ is approximated by the standard normal distribution. The standard normal variate Z is given by,

$$Z = \frac{(\overline{X}-\mu_X)\sqrt{n}}{\sqrt{V(X)}} \tag{4.4}$$

The probability $(1-\alpha)\%$ that the interval constructed contains the true mean μ_X is shown by,

$$P\left(-z_{1-\alpha/2} \leq \frac{(\overline{X} - \mu_X)\sqrt{n}}{\sqrt{V(X)}} \leq z_{1-\alpha/2}\right) = 1-\alpha \tag{4.5}$$

where $z_{1-\alpha/2}$ is in units of standard deviation about Z.

Rearranging yields,

$$P\left(\bar{X} - \frac{z_{1-\alpha/2}\sqrt{V(X)}}{\sqrt{n}} \leq \mu_X \leq \bar{X} + \frac{z_{1-\alpha/2}\sqrt{V(X)}}{\sqrt{n}}\right) = 1-\alpha \qquad (4.6)$$

This states, with probability $1-\alpha$, that $\bar{X}$ falls within the specified interval about the true mean μ_X.

4.3 Observations That Are Auto-correlated

The discussion above utilized the assumption that the observations of waiting time W_j within a simulation run are independent random variables. This is usually not the case. If the waiting time for arrival m is large, then the waiting time for arrival m+1 is likely to be large also. Data related in this manner is said to be auto-correlated.

Since the assumption of independence does not hold for observations of waiting time W_j within a single simulation run, it would be necessary to make multiple runs unless the auto-correlation is accounted for. The mean x_i, of the observations of one run i is given by

$$x_i = \frac{1}{n}\sum_{j=1}^{n} W_{ij} \qquad (4.7)$$

If independent streams of random numbers are used in each run, then each x_i is independent. If N independent runs

are made, then the mean $\overline{X}$ is given by

$$\overline{X} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (4.8)$$

The sample mean $\overline{X}$ is an unbiased estimator for the true mean μ_x. Since each x_i is independent, the relationship between the variance of the sample mean $V(\overline{X})$ and the variance of the true mean $V(X)$ would be

$$V(\overline{X}) = \frac{V(X)}{N} \qquad (4.9)$$

Once again, the true variance $V(X)$ would be estimated by s^2, with x_i substituted for W_j. The rest of the discussion of the previous section holds, with there being N independent runs instead of n observations within a single run.

There are two difficulties with this simplistic approach. First, the number of runs necessary, and hence the cost of the modelling effort, can rapidly grow large. Second, there is much data within a single simulation run that is being discarded and which could be of some use. The following discusses a way to utilize some of this information to reduce the number of independent simulation runs necessary for the level of confidence desired.

The process under discussion is the waiting time of vehicles in the arrival queue. Each W_j is one observation of a waiting time. The mean time in the queue for

a single simulation run is given by

$$\bar{W} = \frac{1}{n}\sum_{j=1}^{n} W_j \tag{4.10}$$

What is desired is $V(\bar{W})$, the variance of the sample mean $\bar{W}$. This cannot be estimated through use of the formula for s^2, as the successive W_j's are auto-correlated. There is theoretical and empirical evidence [Fishman (12)] that for simple queuing systems successive W_j's are related through the following recursion

$$\left[W_{j+1} - E(W)\right] = \xi \left[W_j - E(W)\right] + e_{j+1} \tag{4.11}$$

The correlation coefficient is represented by ξ, and the error term, e_{j+1}, is assumed to be normally distributed with mean of zero and variance σ^2. For any observation of waiting time W_k, the correlation coefficient of that observation and one s observations away, W_{k+s} can be shown to be,

$$\text{cor}\ (W_k\ , W_{k+s}) = \xi^s \tag{4.12}$$

With knowledge of ξ, σ^2, and the number of observations n, equation (4.14) can be developed to obtain $V(\bar{W})$. The σ^2 may be estimated from the data stream, and Sussman and Tumquist (35) have developed an estimator for ξ, as given by

$$\hat{\xi} = e^{-(1-\rho)^2} \tag{4.13}$$

ρ is the utilization factor for the particular queuing system under discussion.

$$V(\overline{W}) = \frac{\sigma^2}{n(1-\xi)^2}\left[1 - \frac{2\xi(1-\xi^n)}{n(1-\xi^2)} - \frac{\xi^2(1-\xi^n)^2}{n(1-\xi^2)}\right] \tag{4.14}$$

At this point the relation between the variance of the sample mean over several runs, $V(\overline{X})$, and the variance of a single run, $V(\overline{W})$, is given by

$$V(\overline{X}) = \frac{V(\overline{W})}{N} \tag{4.15}$$

The number of independent simulation runs, N, necessary to obtain the desired level of confidence in the results, can be obtained from equation (4.15) by re-arranging and substituting $V(\overline{W})$ from equation (4.12) and $V(\overline{X})$, as calculated in the following discussion.

In this thesis, the level of confidence and the interval are exogeneously specified. The expression for one-half the interval is given in equation (4.6). The value of $z_{1-\alpha/2}$ for the desired confidence interval is obtained from a table of the standard normal distribution. The number of observations, n, is determined by the system being modeled. This information is substituted, the expression is set equal to one-half the desired interval, and it is evaluated for $V(\overline{X})$. This value for $V(\overline{X})$ is

then substituted in equation (4.15), and solved for N, the number of simulation runs required. The required number of independent simulation runs were made for the on- and off-street deliveries under the vehicle control policies pertinent to each. The sample mean was obtained by

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} \bar{W} \qquad (4.16)$$

The confidence levels for the results of each model are specified in the following chapters, where the simulation results are shown.

In order to minimize the variance of the estimated difference between mean waiting times under alternative vehicle control policies, separate sequences of random numbers were used for generation of the inter-arrival times and service times for each server. Identical sequences of random numbers were used in the simulation of each vehicle control policy for a particular block or alley.

4.4 Summary

The observations of waiting time from a particular simulation run are not independent random variables, but are auto-correlated. If the observations were erroneously treated as being independent, the variance of the mean wait time will be underestimated. It is possible to make multiple, independent runs of each simulation model, but

this results in much useful data within a run being ignored. More sophisticated treatment of the data results in an estimate of the true variance that is corrected for the autocorrelation effects. The desired level of confidence that the sample mean falls within an interval about the true mean is specified exogeneously. The variance of the sample mean which would result in the specified level of confidence in that interval is calculated. This, and the estimate of the true variance, are used to determine the number of replications of the model required to achieve that level of confidence.

Chapter 5

ON-STREET DELIVERIES

5.1 Introduction

Vehicles that currently make curb-side deliveries on State Street will be diverted to cross-street loading zones under the mall proposal. The mean dwell time for a vehicle will be longer, as the driver must hand carry his delivery farther. The arrival rate for vehicles was calculated using the assumptions discussed in Chapter 3. Using the same arrival rate, simulation runs were made for the present curb-side deliveries and the proposed cross-street deliveries. The results show an increase in time to make a delivery, as a result of this vehicle control policy, which is longer than the time increase attributable to the increased walking distance for the driver.

5.2 Assumptions Underlying the Analysis

Under the State Street transitway proposal, no delivery vehicles will be permitted to make curb-side deliveries on the mall. All deliveries that are currently made in this manner, will be diverted to loading zones on cross-streets. The number and placement of these loading

zones is shown in figure 5-1. The direction of flow of the one-way cross streets is shown also.

Each block was simulated separately as no information on the vehicular interactions between them was available. Assumptions had to be made concerning which loading zones were to serve which blocks. The assumptions made were influenced by several factors, including:

1. The placement of the loading zones;
2. The total and peak hour number of vehicles for each block;
3. The hypothesis that drivers would prefer, where possible, to cart or carry their delivery a longer distance on the sidewalk than attempt to cross the street with it.

Based upon these considerations, the following assignments of loading zones were made:

1. The two loading zones on Lake will serve block #1.
2. The three loading zones on Randolph will serve block #2.
3. The three loading zones on Washington will serve block #3.
4. The three loading zones on Madison and two of the loading zones on Monroe will serve block #4.[1]

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[1]There are no loading zones contiguous to blocks #4 or #6 due to the presence of wrong-way bus lanes there.

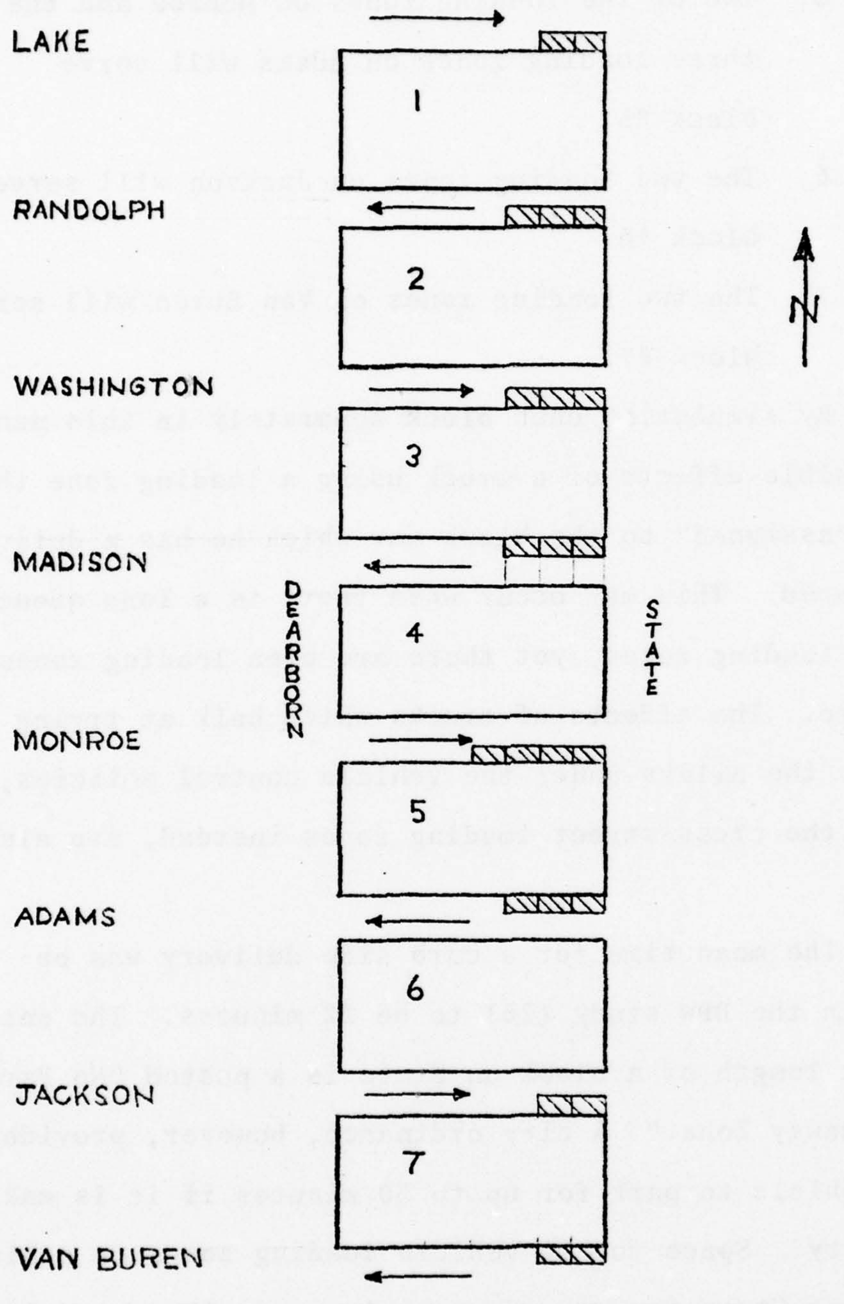

Figure 5-1. Number and Placement of Loading Zones.

5. Two of the loading zones on Monroe and the three loading zones on Adams will serve block #5.
6. The two loading zones on Jackson will serve block #6.
7. The two loading zones on Van Buren will serve block #7.

By simulating each block separately in this manner, the possible effects of a truck using a loading zone that is not "assigned" to the block for which he has a delivery are ignored. This may occur when there is a long queue for the loading zones, yet there are open loading zones elsewhere. The effects of trucks which balk at trying to enter the alleys under the vehicle control policies, and use the cross-street loading zones instead, are also ignored.

The mean time for a curb side delivery was observed in the DPW study (26) to be 22 minutes. The entire 440 foot length of a block on State is a posted "No Parking--Towaway Zone." A city ordinance, however, provides for a vehicle to park for up to 30 minutes if it is making a delivery. Space for 10 vehicle loading zones on a block face along State is not unreasonable, and allows a driver to park relatively close to the retailer to whom he is making the delivery.

Parking on a cross street loading zone will now require the driver to carry or hand truck his delivery, on the average, one half block. At a minimum, one round trip between the delivery vehicle and the retailer would be required. At an average walking speed of 3 mph (264 fpm), the additional service time for a delivery will be about two minutes. Thus, a mean service time for a cross street delivery is assumed to be 24 minutes.

The arrival rates for each time period and for each block are derived using the relationships shown in equations (3.1) and (3.2). The mean of 22 minutes for a curb side delivery and the steady-state value of L when no queue forms are used to calculate the arrival rates. (See Table 5-1). The mean times between arrivals, T_a, are calculated from these and are used as the means of the exponential inter-arrival distributions.

5.3 Simulation Results

Simulation runs were made for the present curb side deliveries, and the proposed cross street loading zones, incorporating the pertinent assumptions above. The results of these simulations are shown in Table 5-2. For each block, as was expected, the total average time to make a delivery increases. The additional time required for a cross street delivery over a curb side delivery ranges from 7.1 minutes on block #7 to 76.5 minutes on block #1. This does not consider the situation

Table 5-1

Arrival Rates for On-Street Deliveries

Block	Time Period Ending	L	λ	T_a [2]
#1	1100[1]	2	0.09090	660
	1200	4	0.18181	330
	1400	2	0.09090	660
	1500	1	0.04545	1320
#2	1000	2	0.09090	660
	1100	3	0.13636	440
	1400	2	0.09090	660
	1500	3	0.13636	440
#3	1000	2	0.09090	660
	1100	2	0.09090	660
	1400	3	0.13636	440
	1500	0	0.0	60000[3]
#4	0930	1	0.04545	1320
	1100	7	0.27272	220
	1215	2	0.09090	660
	1400	1	0.04545	1320
	1500	0	0.0	60000
#5	1000	3	0.13636	440
	1115	5	0.22727	264
	1400	2	0.09090	660
	1500	1	1.04545	1320
#6	1000	1	0.04545	1320
	1100	2	0.09090	660
	1400	1	0.04555	1320
	1500	1	0.04545	1320
#7	1000	1	0.04545	1320
	1300	1	0.04545	1320
	1400	2	0.09090	660
	1500	1	0.04545	1320

[1] Twenty-four hour clock system.

[2] in seconds

[3] since $T_a = 1/\lambda$, $\lambda = 0 \rightarrow T_a = \infty \approx 60000$ seconds

where a driver will balk at the length of the queue and return again later. The increased cost of making a delivery under this policy varies from only $1 on block #5 to $17.50 on block #1. It is evident that the number of loading zones serving block #1 could be increased and thus reduce the increased cost to make a delivery.

Table 5-2

Simulation Results for On-Street Deliveries

Bl.	Policy	Mean No. Vehicles	Interval & Confidence Level	Mean Time Arr. Queue	Mean Time Ser.	Mean Time Total	Cost[1]
1	curb	48	4 @90%[2]	0.0[3]	24.6	24.6	$ 5.60
1	x-street	46	10 @90%	77.7	23.4	101.1	23.10
2	curb	51	4 @90%	0.0	24.2	24.2	5.50
2	x-street	51	4 @90%	15.6	25.1	40.7	9.30
3	curb	48	4 @90%	0.0	24.6	24.6	5.60
3	x-street	43	4 @90%	22.2	25.7	47.9	10.90
4	curb	49	4 @90%	0.4	24.3	25.1	5.70
4	x-street	40	4 @90%	8.9	22.3	31.2	7.10
5	curb	59	4 @90%	0.0	24.0	24.0	5.50
5	x-street	55	4 @90%	2.0	26.3	28.3	6.50
6	curb	28	4 @90%	0.0	23.7	23.7	5.40
6	x-street	24	4 @90%	6.9	24.9	31.8	7.30
7	curb	28	4 @90%	0.0	23.7	23.7	5.40
7	x-street	25	4 @90%	6.2	24.6	30.8	7.00

[1] $13.68 per hour. [2] i.e., mean time in arrival queue is ± 2 minutes 90% of the time.

[3] all times in minutes.

Chapter 6

OFF STREET DELIVERIES

6.1 Introduction

Six east-west alleys are in the study area. The arrival rates for vehicles at each alley was obtained from the observations in the DPW (26) study. The arrival rate for a particular alley was used in the simulation of that alley under each policy. Generally, these policies were simulated: (1) present conditions, (2) closure of each alley at State Street, and (3) time-restricted entry or exit on State for alley access. Each alley was simulated separately. For almost all alleys under each vehicle control policy, the results showed an increase in the total waiting time for a vehicle to make a delivery.

6.2 Description of Setting

There are six east-west alleys in the study area that have vehicular entry from State Street at the present time. They are: Couch, Court, Calhoun, Arcade, Marble and Quincy. These are shown in figure 6-1, numbered consecutively for convenience. Except for Quincy, the alleys are very narrow, 15' to 18' wide. This is a nominal width and does not account for numerous protrusions from buildings which reduce the effective width. A standard 18 to

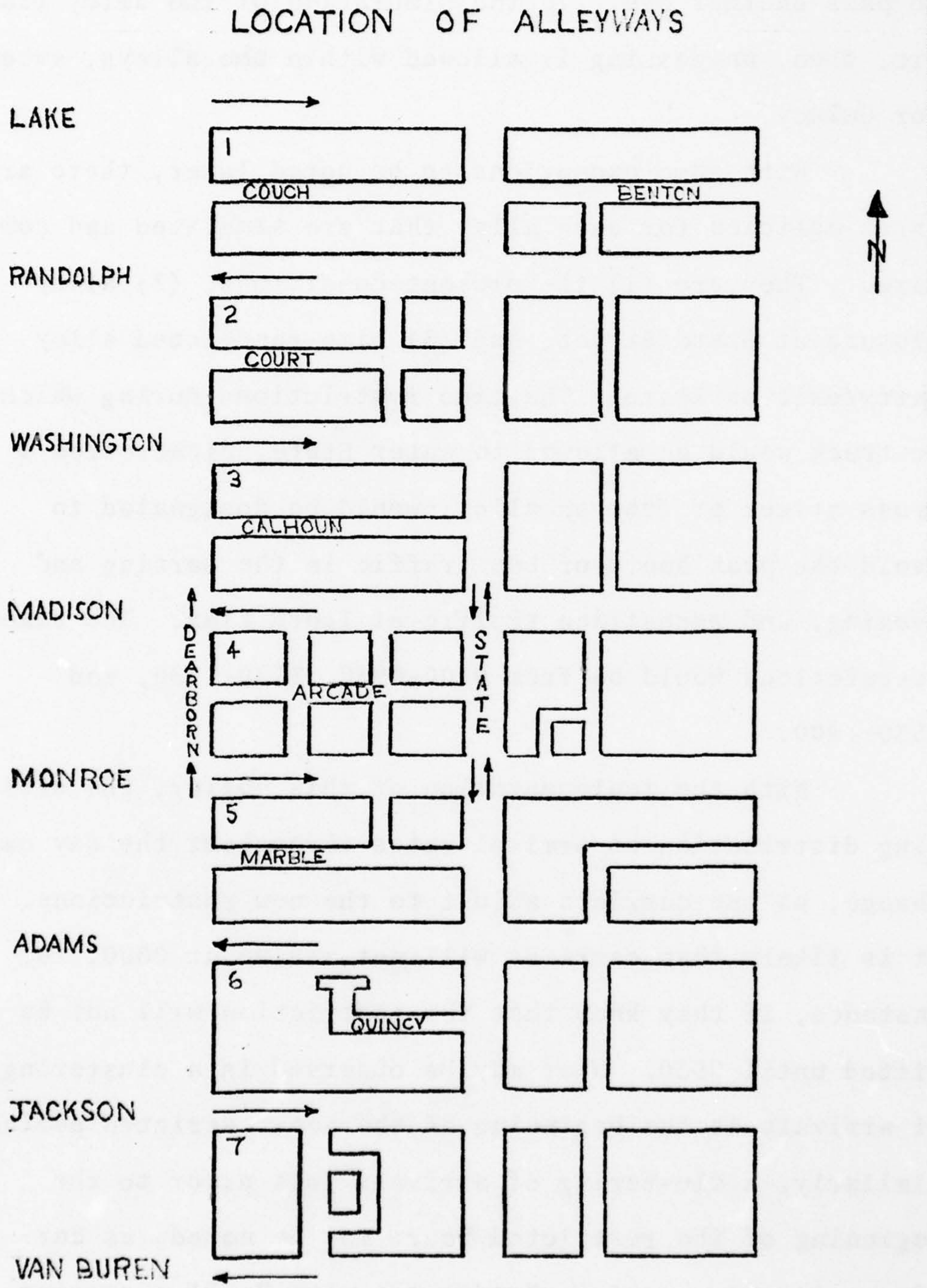
LOCATION OF ALLEYWAYS
LAKE
RANDOLPH
WASHINGTON
MADISON
MONROE
ADAMS
JACKSON
VAN BUREN
1
COUCH
BENTON
2
COURT
3
CALHOUN
4
ARCADE
5
MARBLE
6
QUINCY
7
DEARBORN
STATE
N

Figure 6-1.

20 foot straight truck would find it virtually impossible to pass another one. In the simulation of the alley traffic, then, no passing is allowed within the alleys, except for Quincy.

With some exceptions to be noted later, there are three policies for each alley that are simulated and compared. They are (1) the present conditions, (2) alley closure at State Street, and (3) time-restricted alley entry/exit on State. The time restrictions during which no truck would be allowed to enter State, either from a cross street or from an alley, would be designated to avoid the peak hours of bus traffic in the morning and evening, and pedestrian traffic at lunch time. The time restrictions would be from 0700-0930, 1130-1330, and 1530-1800.

With the implementation of this policy, the existing distribution of arrival rates throughout the day may change, as the carriers adjust to the new restrictions. It is likely that carriers will not arrive at 0800, for instance, if they know that the restriction will not be lifted until 0930. What may be observed is a clustering of arrivals at the beginning of the non-restricted period. Similarly, a clustering of arrivals just prior to the beginning of the restricted hours may be noted, as carriers attempt to get in "under the wire." If a carrier has multiple deliveries, some of which are to merchants

in the downtown, but not in the mall area, they may be performed during the mall restricted hours. This potential change in arrival rates as a result of the time restriction implementation is not accounted for in the simulation model, as no estimate of it could be made.

Closure of the alleys at State would, except for Quincy, require vehicles to enter and exit from the alleys on Dearborn Street. To avoid serious congestion in the alleys, it is necessary to enforce a queuing discipline that requires a vehicle to wait on Dearborn, outside the alley, until a dock or loading door becomes available for him. In this situation, it is possible for the trucks to maneuver around one another in the queue as their particular server becomes available.

Generally, the present traffic flow in the alleys is one-way from north to south and from east to west. Although illegal, it is quite common for a truck to exit the "wrong way" rather than incur delay if the western end of the alley is blocked. For practical and safety reasons, no truck is allowed to attempt backing in or out of an alley. This is reflected in the simulation model.

From the DPW study (26) the mean service time for an alley delivery, at a loading door or a dock is 30 minutes. This does not include waiting time for access to a server or waiting time for alley exit upon

completion of the delivery. These latter two quantities are separately tabulated in the simulation run.

The model does not account for any additional cruising time that a truck may incur as a result of increased traffic on cross streets, nor does it consider congestion effects on Dearborn caused by a queue waiting for alley entry.

The arrival rate λ, in units of number of arrivals per hour, for each alley is shown in table 6-1. The arrival rates were obtained from (26). The mean interarrival times T_a were calculated and converted to seconds for use in the simulation model. The arrival rate was assumed to go to zero after 1800.

6.3 Alley #1--Couch

The policy of closure at State is not feasable here, as the alley has no docks at which the turning movement could take place. Figure 6-2a depicts the vehicular flow in the alley as it is at present. Vehicles proceed south bound on State and enter the east end of the alley. The exit onto Dearborn and proceed north bound. There are three loading doors that are serviced by the alley, two on the south and one on the north. Trucks that service these doors occupy space at S_1, S_2, and at S_3 while doing so. Additionally, there is sufficient space (S_{21}, S_{22}) for two trucks to queue in the alley while waiting

Table 6-1

Arrival Rates for Off-street Deliveries

Alley No.	1		2		3		4		5		6	
Hour Ending	T_a	λ	T_a	λ	T_a	λ	T_a	λ	T_a	λ	T_a	λ
0900	2	1800	6	600	16	225	1	3600	7	514	9	400
1000	2	1800	4	900	12	300	2	1800	10	360	15	240
1100	2	1800	9	400	5	720	0	60000[1]	15	240	13	276
1200	5	720	9	400	7	514	2	1800	12	300	4	900
1300	0	60000	4	900	5	720	6	1200	9	400	7	514
1400	0	60000	3	1200	6	600	5	720	12	300	2	1800
1500	4	900	4	900	2	1800	1	3600	3	1200	8	450
1600	5	720	3	1200	13	277	0	60000	5	720	2	1800
1700	2	1800	4	900	2	1800	0	60000	11	327	0	60000
1800	5	720	1	3600	0	60000	0	60000	3	1200	0	60000
Arrivals Per Day	27		47		68		17		87		60	

[1]Since $T_a = 1/\lambda$, $\lambda = 0 \rightarrow T_a = \infty \approx 60000$

for service at S_2 or S_3 or while waiting for alley exit upon completion of service at S_1.

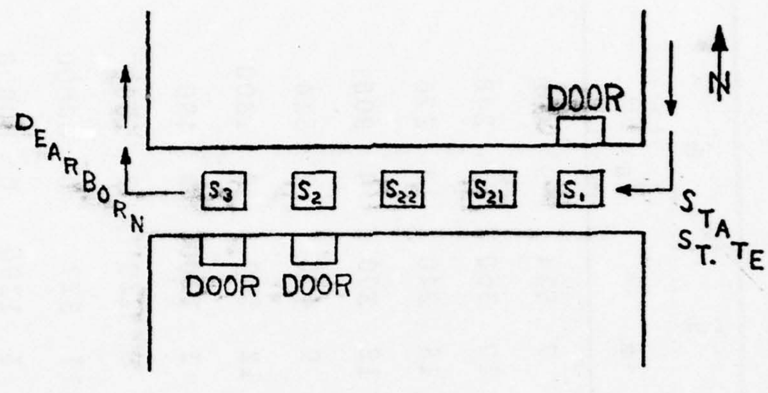

Figure 6-2a. Present Conditions Alley #1, Couch

Trucks first queue on State, and are able to maneuver around one another if the destination loading door of a particular arrival opens up prior to the one for the trucks ahead of him in the queue. Thus alley entry is not strictly first come first served. A uniform distribution of loading door destinations was assumed, as no better estimate was available. Once a truck has entered the alley, however, there is insufficient alley width for passing to take place. This results in congestion effects. For example, if three trucks arrived in rapid succession and were waiting for the door at S_2 to become free they would occupy space S_{22}, S_{21}, and S_1. A truck arriving for delivery at S_1 would not be able to enter the alley and perform the delivery function, even though the door at S_1 is not in use.

The vehicular flow for the time-restricted exit policy is shown in figure 6-2b. Trucks would now queue on Dearborn and enter the alley from the west. As in the present case, a uniform distribution of arrivals to loading door destinations is assumed. Trucks would exit only during the non-restricted hours by crossing State, and departing through the larger alley, Benton. This restricted crossing is to preserve the pedestrian environment on the mall.

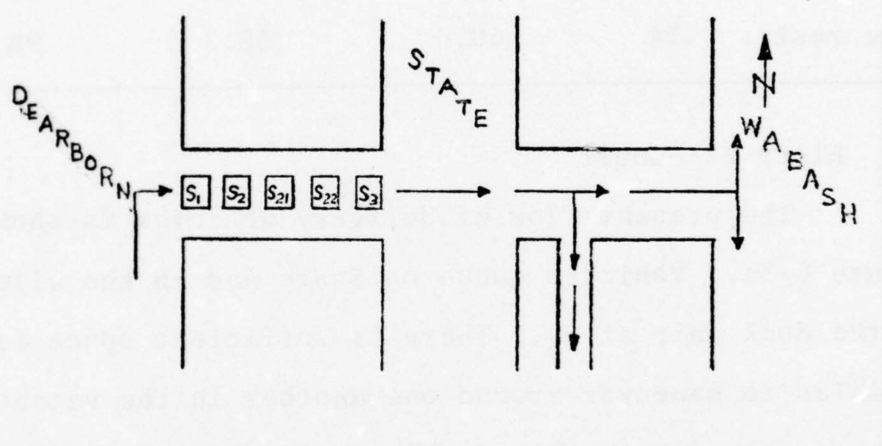

Figure 6-2b. Time Restricted Policy Alley #1--Couch

A comparison of the results of simulation runs of the present conditions and the time-restricted exit policy is shown in Table 6-2. As might be expected, the imposition of a policy of time-restricted exit will increase the waiting time for trucks to depart the alley. The blockage caused by this time restriction will cause trucks to "back up" in the alley, blocking the loading doors, and increase

the waiting time for entry to the alley as well. This increase in total average delay amounts to 41.8 minutes per delivery.

Table 6-2

Simulation Results Alley #1--Couch

Policy	Mean No. Vehicles	Mean time Entry Queue	Mean Time Exit Queue	Total Avg. Delay
present	16	49.2	7.8	57
time restr.	14	60.6	38.2	98.8

6.4 Alley #2--Court

The present flow of delivery vehicles is shown in figure 6-3a. Vehicles queue on State and in the alley east of the dock pair at S_3. There is sufficient space for the vehicles to maneuver around one another in the vacant lot if a truck's destination dock becomes available. The alley contains one loading door and two dock pairs for two different retailers. The north-south alley is of insufficient width to permit use by trucks. A vehicle at one of the docks will not block passage past that dock by another vehicle. A vehicle at the loading door, S_1, will effectively block entry and exit to the west docks, S_2. If alley traffic flow is observed, a vehicle at S_1 would also obstruct exit from the alley for a vehicle from the east docks, S_3,

as well. In actual practice, however, a truck which has completed its delivery at S_3 will not wait for S_1 to finish, but will use the vacant lot to maneuver around the trucks in the queue and will exit the alley the "wrong way" on to State. For purposes of analysis of present conditions, a vehicle at S_1 will interfere with neither entry to nor exit from S_3.

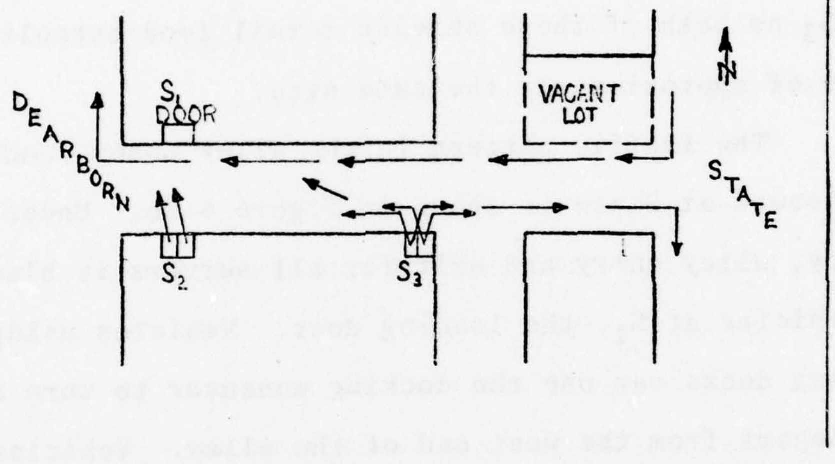

Figure 6-3a. Present conditions Alley #2 Court

There is little information available on the destination dock or door of a vehicle entering the alley. The distribution of destinations is, however, an important parameter of the analysis. Figure 6-3a illustrates how the percentage of vehicles that are delivering to the loading door can have a significant effect upon the delay time for entry to and exit from the west docks. Estimates of vehicles using the loading door range from 30% to 40% of the

total number of vehicles entering the alley,[1] somewhat above the 20% that one would assume if there was a uniform distribution among the 5 available loading spaces. In an attempt to determine this impact, the number of vehicles destined for the loading door was varied from 20% to 50% of the total number entering the alley for the present, the closure, and the time restricted policies. The remaining vehicles were uniformly distributed between S_2 and S_3 as both of these service retail food establishments of approximately the same size.

The traffic pattern in the alley under conditions of closure at State is shown in figure 6-3b. Under this policy, alley entry and exit for all servers is blocked by vehicles at S_1, the loading door. Vehicles using the loading docks can use the docking maneuver to turn around and depart from the west end of the alley. Vehicles using the loading door must pull past the docks upon completion of the delivery, use the vacant lot for the turning maneuver, and then exit from the west end of the alley. Vehicles will queue on Dearborn for entry to the alley.

At this time, development of the lot is under consideration. If a building is constructed on the lot, the delivery door vehicles will no longer have a turnaround

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[1] Source: Personal communication with personnel from the retailer whose deliveries are received at the loading door, S_1.

and, will be forced to exit onto State Street. The vehicles serving the loading docks will still be required to enter and exit from the west end of the alley. (See figure 6-3c). East of S_3, there is adequate space (S_{11}, S_{12}, S_{13}) for three vehicles waiting for alley exit onto State. If all three are full, the vehicle at S_1 will be unable to pull forward, and all servers will be blocked.

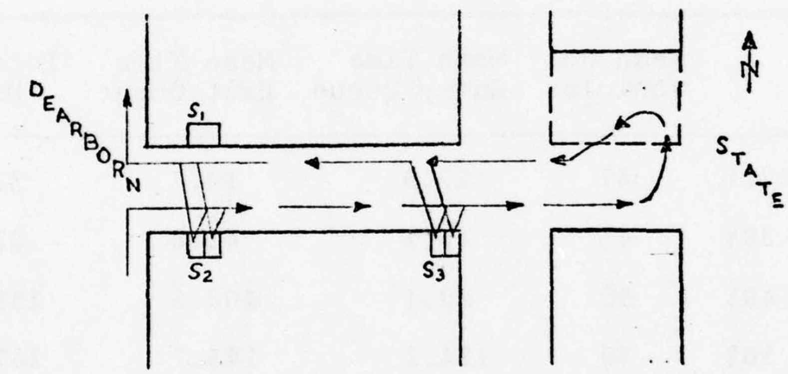

Figure 6-3b. Closure at State Alley #2 Court

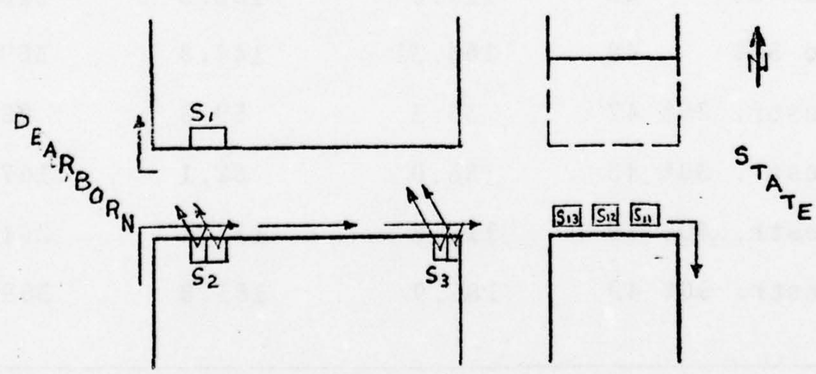

Figure 6-3c. Time Restricted Exit Alley #2 Court

The results of the simulation runs of this alley for the present conditions, State closure, and time-restricted exit policies with the percentage of vehicles destined for the loading door ranged from 20% to 50% are shown in Table 6-3.

Table 6-3

Simulation Results Alley #2 Court

Policy	Mean No. Vehicles	Mean Time Entry Queue	Mean Time Exit Queue	Total Avg. Delay
present 20%	47	17.9	14.7	32.6
present 30%	43	40.1	42.0	82.1
present 40%	50	88.1	100.3	188.4
present 50%	49	124.2	143.7	267.9
closure 20%	47	28.4	15.0	43.4
closure 30%	43	80.4	46.5	126.9
closure 40%	50	117.6	100.9	218.5
closure 50%	48	164.31	144.8	309.1
time restr. 20%	47	35.3	59.8	95.1
time restr. 30%	43	85.0	82.1	167.1
time restr. 40%	49	119.2	132.1	251.3
time restr. 50%	49	185.9	183.8	369.7

Under all policies, the percentage of vehicles that must use the loading door is indeed a critical number.

In addition, it is of some importance in interpreting these results to know the arrival pattern through the course of the day for each of the three servers themselves, instead of an aggregate for the entire alley. For example, the distribution of the 50% of the vehicles to the door is assumed uniform throughout the day. If in fact those 50% entered mostly in the afternoon, and the vehicles destined for the docks entered mostly in the morning, a different picture might be painted, as a difference in congestion effects would exist.

With presently available information, the increase in time to make a delivery (Total Average Delay) over the present situation is estimated to range from 10.8 minutes for the closure policy and 62.5 minutes for the time-restricted exit policy with 20% of vehicles going to loading door, to 41.2 minutes for closure and 101.8 for time restricted exit with 50% of the vehicles going to the loading door.

6.5 Alley #3--Calhoun

The existing vehicle flow for alley #3 is shown in figure 6-4a. At first glance, it may seem similar to alley #2; however, there are some important differences. Vehicles queue in the alley for service, and the queue extends on to State. Vehicles queue in the alley in order of arrival and there is insufficient alley width

to permit one to maneuver around another. A truck may not move up in line until the space in front of it is cleared. There is space (S_{11}, S_{12}, S_{13}) for three vehicles to queue in the alley. When a vehicle has reached the head of the line, it must wait in place until its server opened up.

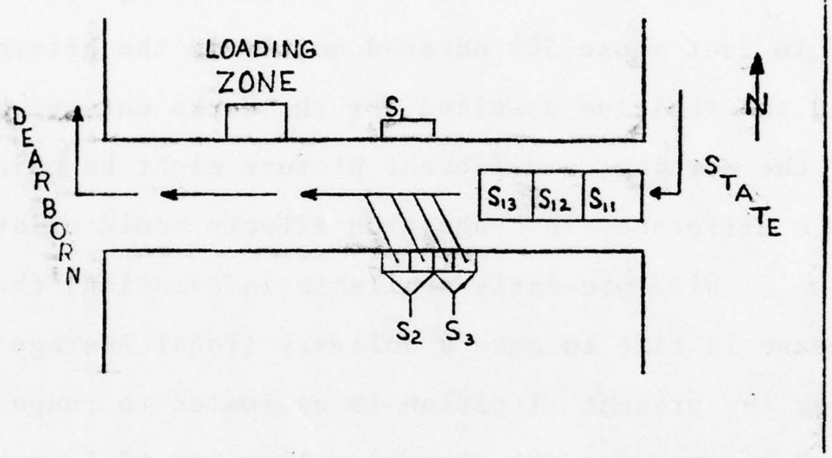

Figure 6-4a. Present Conditions Alley #3 Calhoun

There are four docks and one loading door in the alley. There is also a little used loading zone on the northern side of the alley to the west of S_1. The four docks serve the same retail building. A vehicle at the loading door, S_1, will block entry and exit for one dock pair, S_2. Entry to the other dock pair, S_3, is not blocked by S_1. A vehicle completing service at S_3 will attempt to exit the "wrong way", if S_1 is blocking the western exit, and if there is no queue in the eastern end of the alley. Otherwise, it must wait in place for S_1 to clear.

The four docks were simulated as parallel servers, with the exception that entry was attempted at dock pair S_3 first, before testing if S_2 was full.

The vehicular flow under the closure policy is shown in figure 6-4b. A .ehicle at S_1 the loading door, will block both entry and exit for all dock vehicles, thus the four docks are simulated as four parallel servers. Dock vehicles can turn around through the docking maneuver. Loading door vehicles can back a short distance to the loading zone and turn around, or use an empty dock at S_2 if it is available. Vehicles will queue for alley entry on Dearborn, and will not be permitted to enter until there is a server open for them. If the server opens up for a vehicle not at the head of the queue, that vehicle can maneuver around trucks in front of it.

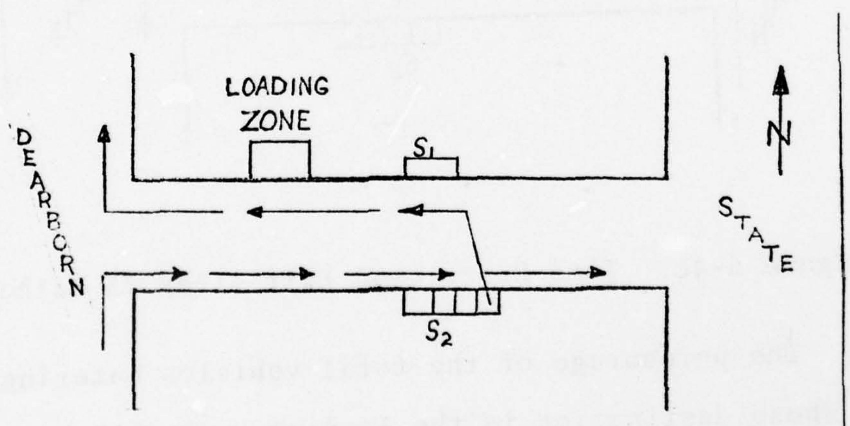

Figure 6-4b. Closure at State Alley #3 Calhoun

The possibility exists that permission may not be obtained to utilize the loading zone or one of the loading docks as a turnaround for the loading door vehicles. If this occurs, a policy of time-restricted exit would be implemented for the loading door vehicles only. (See figure 6-4c). The vehicles serving the loading docks will still be required to enter and exit from the west end of the alley. There are three spaces (S_{11}, S_{12}, S_{13}) for vehicles to queue to exit to State. When these three are occupied, the vehicle in S_1 is blocked, and thus, all servers are blocked.

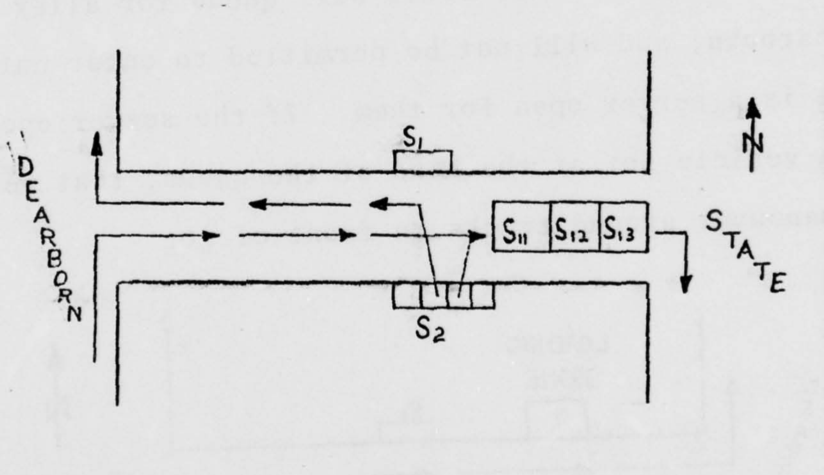

Figure 6-4c. Time—Restricted Exit Alley #3 Calhoun

The percentage of the total vehicles entering the alley whose destination is the loading door will have a critical effect upon the operation of the alley. Little information is available on which to base estimates of

this percentage. For the present, the closure, and the time restricted policies, simulation runs were made with the percentage of 20% and at 30%. The results are shown in table 6-4.

Table 6-4

Simulation Results Alley #3 Calhoun

Policy	Mean No. Vehicles	Mean Time Entry Queue	Mean Time Exit Queue	Total Avg. Delay
present-20%	68	127.9	32.0	159.9
present-30%	68	191.7	66.9	258.6
closure-20%	68	82.3	51.2	133.5
closure-30%	68	159.8	118.5	278.3
time restr.20%	68	89.2	86.7	175.9
time restr.30%	69	179.1	160.0	339.1

Note that the total average delay for the 20% case drops 26 minutes from the present situation to the closure case. This is a result of the mean time in the entry queue being the highest for the present conditions, due to the queuing discipline involved. Presently, vehicles queue in the alley on the order in which they arrive. For a vehicle not at the head of the queue, no maneuvering is allowed in the confines of the alley for him to access his server if it opens up. This truck cannot move up until the vehicle in front of him has occupied his respective server.

This is not the case with either the closure or the time restricted exit policies. Since the vehicles in both these cases queue on Dearborn for alley entry (and can maneuver), and no entry is permitted unless a server is open, the congestion effects observed in the present situation do not take place.

6.6 Alley #4--Arcade

The existing vehicular flow for this alley system is shown in figure 6-5. There are two north-south alleys in this block, the easternmost of which serves the retailers facing State Street. This alley has two loading doors in the northern half of the block, and one loading door and one dock pair on the southern half of the block.

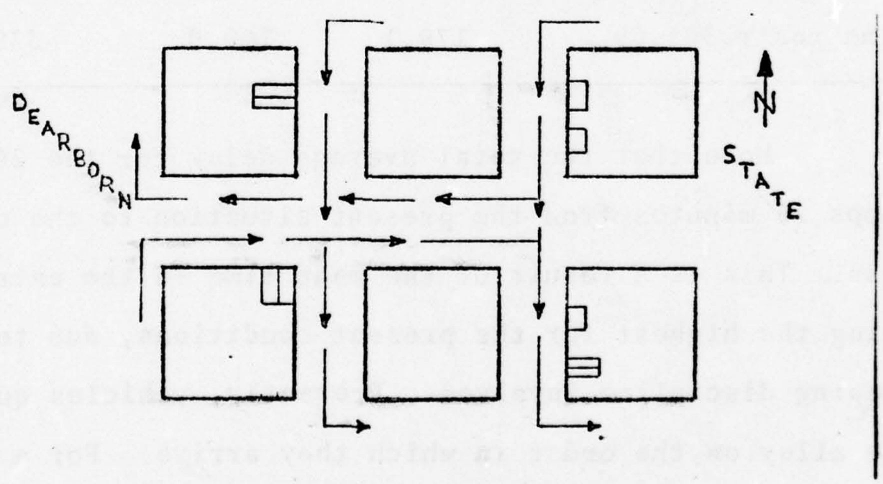

Figure 6-5. Present Conditions Alley #4--Arcade

The decision was made not to simulate this alley for three reasons. First, the number of vehicles entering Arcade from State Street was the lowest of all the alleys in the study. Second, on site observation by the author noted in a short period of time serveral vehicles using Arcade as a "short-cut" between State and Dearborn. Third, the loading doors and docks that serve the retailers on State Street are accessed by the north-south alley.

It does not seem that closure of State Street will severely impare delivery vehicles making off-street deliveries to this block. The two loading docks at the west end of the alley can be accessed from Dearborn. As the cross streets will remain open, access to the north-south alleys will remain as at present. Therefore, this alley was not simulated.

6.7 Alley #5--Marble Place

The present vehicular flow is shown in figure 6-6a. There are two straight loading docks and four angled docks in the alley, all of which serve the same retailer. One of the docks, however, is occupied all day by a trailer which is dropped off at night; thus only five docks are available for daytime usage. All trucks entering the alley are destined for this establishment, and the alley was treated as having five parallel servers. Of special note here, is the fact that four docks are angled in such

a manner so as to require a vehicle to approach from the east before backing into the dock.

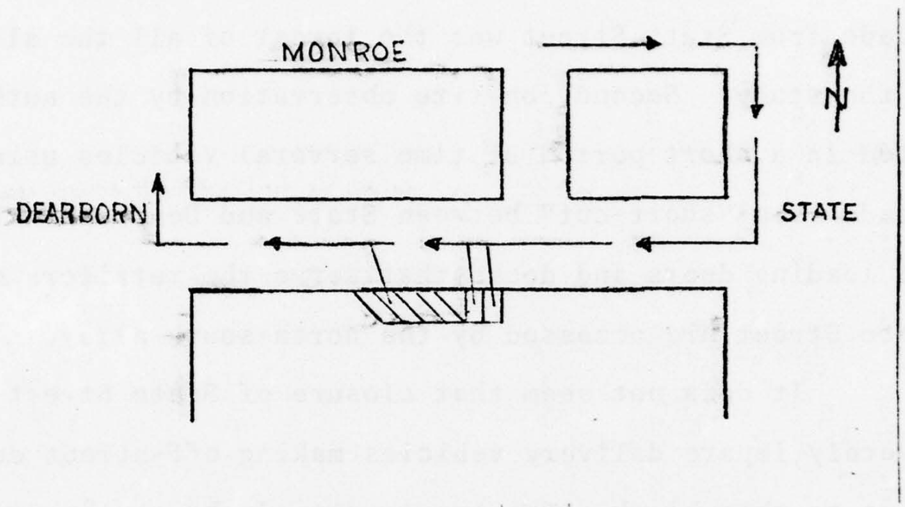

Figure 6-6a. Present Conditions Alley #5 Marble

Trucks queue in the alley, and onto State without blocking any servers. Alley entry and the delivery function are performed on a first come, first served basis.

The nature of the angled docks would preclude closure of the alley at State, requiring both entry and exit from Dearborn, unless some provision is made for the turning movement of the trucks. One proposal to accomodate this is shown in figure 6-6b. The building facing State on the north side of the alley would be acquired, and demolished, and the land used as a turnaround. Vehicles would queue on Dearborn, and entry to the alley would not be permitted unless there was a dock available. This queuing discipline with the closure policy would

result in the same observed delay times (ignoring the additional time to maneuver the truck in the turnaround area) as the present conditions. Thus, the results of the simulation run for the present conditions adequately describes the closure case as well.

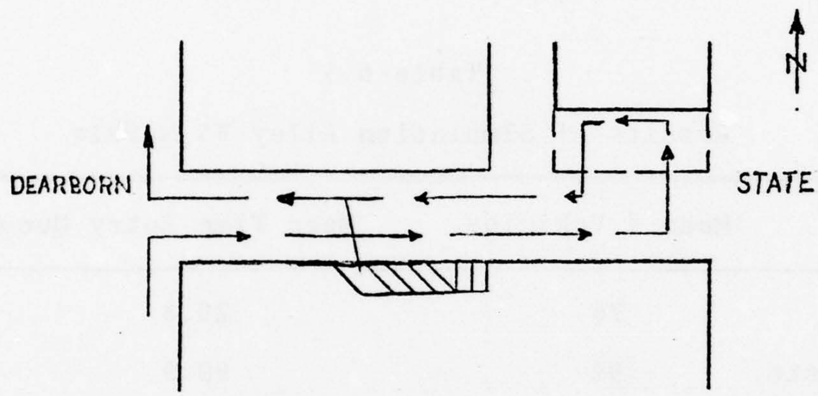

Figure 6-6b. Closure at State Alley #5 Marble

The remaining alternative is the use of the time-restricted entry policy. In this situation, the vehicular flow would be the same as for the present conditions as shown in figure 6-6a, but entry to State, and subsequent entry to the alley, would not be permitted during the restricted hours. Trucks would queue on Monroe, the cross street on the northern edge of the block, while waiting for the time restrictions to be lifted. The possible interference here with the trucks using the cross street loading zones is not accounted for in the model.

Simulation runs of the alley for the time-restricted entry policy and the present conditions (describing the closure case as well) are shown in Table 6-5. The imposition of a time-restriction on entry of vehicles causes an increase in average waiting time of 70.1 minutes per delivery.

Table 6-5

Results of Simulation Alley #5 Marble

Policy	Mean # Vehicles	Mean Time Entry Queue
present	76	29.8
time restr.	92	99.9

6.8 Alley #6--Quincy Street

Quincy Street is the only dead-end alley off of State. Complete closure would be infeasible, as it would leave no access whatsoever to the loading doors and zones in this alley. One closure possibility is a policy of time restricted access across the Federal Building plaza; however, the General Services Administration (GSA) opposes this solution. If it were permitted, the time-restriction to avoid pedestrian peak flows would be essentially the same as for the time-restricted entry/exit to State. A trade-off in the decision between access across the plaza

and access through State is the degradation of the pedestrian environment that would occur in either case. One could speculate that the retailers on State would prefer to maintain the environment on the mall for their customers, rather than the environment for the pedestrian having business in the Federal Building. In either case, however, the time-restricted access would have the same effect upon delivery vehicles.

As shown in figure 6-7, there is space for seven delivery vehicles in this alley, although illegally parked autos can reduce this number. There is sufficient maneuvering room for the trucks to enter and exit independently. With no data on the number of vehicles destined for each establishment, the alley was treated as having seven parallel servers.

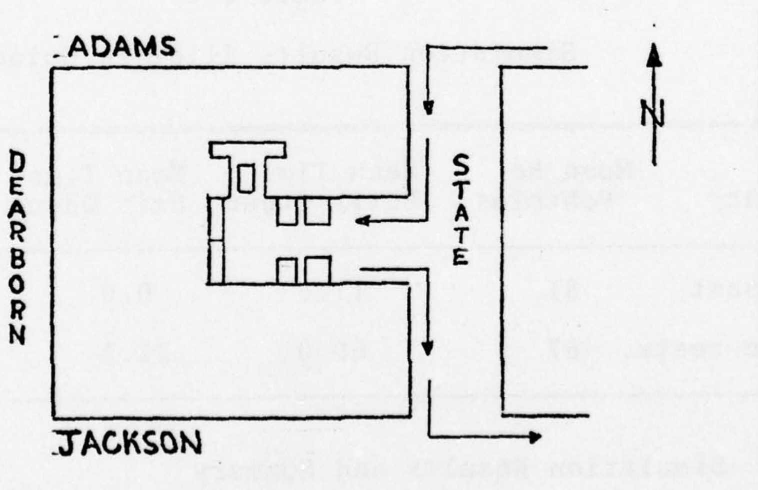

Figure 6-7. Present Conditions Alley #6 Quincy

As closure is not feasible, a policy of time-restricted entry and exit to the alley is proposed. Vehicles would queue for entry to State on Adams, a one-way cross street on the northern edge of the block. Entry would be on a first come, first served basis, and would not be permitted unless a server were available. Vehicles would have to remain in place in the alley when the time-restriction was in effect.

Table 6-6 presents the results of simulation runs for the present and the time-restricted situations. Under present conditions, there is no exit queue; upon completion of its delivery, a vehicle departs. The time-restriction policy increases the total average delay by 70.6 minutes per delivery.

Table 6-6

Simulation Results Alley #6 Quincy

Policy	Mean No. Vehicles	Mean Time Entry Queue	Mean Time Exit Queue	Total Avg. Delay
present	81	11.6	0.0	11.6
time restr.	67	60.0	22.2	82.2

6.9 Simulation Results and Summary

Five east-west alleys were modeled. Each alley has a unique combination of servers and congestion problems.

Alley #4, Arcade, was not simulated, as it has a low volume of delivery vehicles and the existing data on vehicles entering the alley includes both trucks making deliveries and those simply going through. Generally, three policies were simulated for each alley: (1) present conditions, (2) closure of the alley at State Street, and (3) time restricted entry or exit on State for alley access. The time-restrictions were designed to avoid the presence of trucks on the mall during peak transit and pedestrian use.

As the destination server was not known in most cases for vehicles entering each alley, a uniform distribution among servers was assumed. Due to the critical nature of alley obstruction by a vehicle at the loading door in alley #2 and alley #3, the percentage of vehicles destined for each of these varied over a range to test the sensitivity of that assumption.

Determination of the number of simulation runs required for each alley under each policy was made using the techniques discussed in chapter 4. The confidence interval and level for the mean wait time was initially set at 4 minutes and 90%. This proved infeasible for policies where the variance of the observed waiting times was large. The number of simulation runs required for these would have been in excess of a thousand. Since the budget constraint on computer time was a factor, the interval was

widened and the confidence level reduced in some cases. The results for each alley simulated are summarized in Table 6-7. Alley closure is infeasible for alleys 1 and 6. There will be no change in costs for deliveries in alley #5 as a result of closure, due to the vehicular flow involved. The cost per delivery in alley #3, with the assumption of 20% of vehicles entering the alley going to the door, actually is less under the closure policy. This is due to the queuing discipline observed under this policy and subsequent reduction of congestion within the alley. Under the 30% assumption, the increase is less than it might otherwise have been. Alley #2's deliveries will experience an increase in costs under all assumptions as to the percent of delivery door vehicles.

The time-restricted entry/exit to State imposes the most severe cost increases on all of the alleys. Again, the increased cost for alley #3 may be less than it might otherwise have been, due to the change in queuing discipline observed. It is interesting to note that the policy of time restriction of delivery vehicles is most often put forth as the quickest and easiest policy to implement. The perceived social costs of delivery vehicles may be reduced, but significant costs are transferred to the carriers.

Table 6-7

Simulation Results for Off-street Deliveries

Alley	Policy	Mean No. Vehicles	Interval & Confid.Level	Mean Time Entry Queue	Mean time Exit Queue	Total Avg. Delay	Cost[1]
1[2]	present	16	4@90%[3]	49.2[4]	7.8	57	$13.00
1	time restr.	14	4@90%	60.6	38.2	98.8	22.50
2	present-20%	47	4@90%	17.9	14.7	32.6	7.40
2	present-30%	43	4@90%	40.1	42.0	82.1	18.70
2	present-40%	50	10@70%	88.1	100.3	188.4	43.00
2	present-50%	49	10@70%	124.2	143.7	267.9	61.00
2	closure-20%	47	4@90%	28.4	15.0	43.4	9.90
2	closure-30%	43	4@90%	80.4	46.5	126.9	28.90
2	closure-40%	50	10@90%	117.6	100.9	218.5	49.80
2	closure-50%	48	10@70%	164.3	144.8	309.1	70.50
2	time restr.20%	47	4@90%	35.3	59.8	95.1	21.70
2	time restr.30%	43	4@90%	85.0	82.1	167.1	38.10
2	time restr.40%	49	10@90%	119.2	132.1	251.3	57.30
2	time restr.50%	49	10@70%	185.9	183.8	369.7	84.30

Table 6-7 (continued)

Alley	Policy	Mean No. Vehicles	Interval & Confid.Level	Mean Time Entry Queue	Mean Time Exit Queue	Total Avg. Delay	Cost[1]
3	present-20%	68	10@90%	127.9	32.0	159.9	$34.50
3	present-30%	68	15@90%	191.7	66.9	258.6	59.00
3	closure-20%	68	4@90%	82.3	51.2	133.5	30.40
3	closure-30%	68	10@90%	159.8	118.5	278.3	63.50
3	time restr.20%	68	4@90%	89.2	86.7	175.9	40.10
3	time restr.30%	69	10@90%	179.1	160.0	339.1	77.30
5	present[5]	76	10@90%	29.8	n/a	29.8	6.80
5	time restr(entry)	92	10@90%	99.9	n/a	99.9	22.80
6[2]	present	81	4@90%	11.6	n/a	11.6	2.60
6	time restr(exit)	67	4@90%	60.0	22.2	82.2	18.70

[1]$13.68 per hour

[2]closure not feasible

[3]i.e., mean time in arrival queue is ±2 minutes 90% of the time

[4]all times shown in minutes

[5]same results for closure as well

Chapter 7

Alternatives to Increased Costs

7.1 Introduction

The State Street transitway is going to be built, and the vehicle control policies discussed in previous chapters will be implemented. The simulation models for the on- and off-street deliveries have shown that there is going to be an increase in the time to make a delivery. Since the amount of man-hour and truck-hour input necessary to produce a delivery will go up, the cost function will increase for the carriers. The carrier will increase the price (rate) he charges to make a delivery to the retailer.

7.2 Policy Changes

The actual physical acts involved in making a delivery, i.e., the unloading of the goods, the signing of the bills of lading, etc., have not experienced an increase in time, except in the situation with the cross-street loading zones, where now the driver must walk farther to make his delivery. The percentage of the total time (wait time plus actual physical unloading time) that is devoted to idle waiting has increased under the vehicle control policies. The key is to propose some policy or some facility which will enable a carrier to reduce this idle

time. The obvious trade-off is between the cost of such a scheme and the costs of performing deliveries under the vehicle control policies.

One could approach this attempt to reduce costs on a block by block or an alley by alley basis. A simple example is the very sharp increase in waiting time that is observed on block number one. This could be reduced by the provision of a third loading zone servicing this block. Another example is the interference and congestion caused by the vehicles delivering to the loading doors in alleys #2 and #3. It has been shown that the number of vehicles destined for these doors can have a significant effect upon the waiting times for almost all the other vehicles entering these alleys. If the distribution of arrivals to the door and the docks individually were known for each of these alleys, it might be possible to schedule the arrivals for these so as to off-set the peaks of both.

This type of approach, although having some merit, is piecemeal and does not permit one to view the problem in its entirety. As discussed above, a means is needed to keep the idle time of the carriers to a minimum. Various technological innovations have been proposed to facilitate distribution of goods from the delivery vehicle to the retailer in downtown areas. These include tube systems,

conveyors, etc., all of which are automated to a high degree. Implementation of any of these concepts would require a massive capital investment to provide the infrastructure. They will not be discussed here.

7.3 Consolidated Receiving Facility

With present technology, there is at least one proposal that would serve to reduce the carrier's time to make a delivery under the vehicle control policies. This would be the provision of a consolidated receiving facility contiguous to the mall for deliveries to all but the largest retailers on the mall. The larger retailers already consolidate smaller shipments into larger ones for their downtown stores to a great degree. This receiving facility could be compared to the central receiving room of a large industrial plant. The problem then becomes one of physical distribution of goods to individual retailers in a controlled environment, i.e., the mall area. If the facility were properly sized, it would serve to reduce the idle time of the carriers through quick in and out service. It is conceivable that the times might even be less than those observed under present conditions. The internal distribution of goods from the central receiving facility could be performed by smaller, perhaps electrically powered vehicles that could share the pedestrian right of way. These

smaller vehicles would make scheduled runs to each block; the number of vehicles and frequency of runs could be planned with presently available information on the requirements of each retailer. Since the operation of the facility and the redistribution of goods would be under the control of a single manager responsive to the retailers, a more uniform rate of arrival of goods at the individual retailer could be achieved.

The trade-off here is between the cost to the carriers of operation under the vehicle control policies with the present facilities, and the construction and operation of the central receiving facility scheme. As calculated from the results in table 6-2, the increased cost as a result of diversion of curb side deliveries to cross street loading zones would be over $7,000 per week for the study area. The simulation results for the alley deliveries in table 7-7 show an increased cost to the carriers of $14,000 to $30,000 per week, depending upon the policy evaluated and the assumptions concerning the loading doors in alleys #2 and #3. If these increased costs are thought of in terms of increased rates to the retailer, the concept of a consolidated receiving facility becomes attractive.

In considering the dollar value given to the results alone, one must be wary of using them directly in a cost/benefit analysis to justify such a facility.

They are indicative of the magnitude of the cost increases to the carrier, but this is over a very short time span. To compare these directly with long range investment in a fixed facility could result in erroneous interpretations of the results.

Chapter 8

SUMMARY AND CONCLUSIONS

8.1 Summary

This thesis has investigated the cost impacts to carriers resulting from two vehicle control policies that could be used to direct the flow of delivery vehicles which service downtown shopping malls. These control policies were complete delivery vehicle prohibition from the mall and time-restricted access by delivery vehicles upon the mall. Most studies to date have proposed control policies as means of reducing perceived social costs of truck pick up and delivery operations. Relatively little consideration has been given to the costs that the carriers would incur if these policies were introduced. The proposed State Street transitway/mall in Chicago was selected as a case study to evaluate the cost impacts of these policies.

Imposition of a vehicle control policy will cause an increase in the amount of time necessary to make a delivery and will shift the carrier's short run marginal cost curve upward. As there is no rate regulation of local cartage companies in the Chicago Commercial Zone, a carrier will be able to increase the rate he charges

for a delivery to the retailer. At the same time, the expected increase in retail sales as a result of the mall construction may increase the retailer's demand for deliveries. The cost of time was approximated by the man-hour cost to the carrier.

A queuing model was constructed in order to show the increased time it takes to make deliveries under the proposed vehicle control policies. The arrival data was obtained from a study by the Chicago Department of Public Works (26). A Poisson arrival pattern was assumed. The service data from the DPW study was inadequate for use in the queuing model, as no information of the distribution of service times was collected. A study by the Polytechnic Institute of New York (9) had fitted a gamma distribution to the delivery times observed at different land uses in Brooklyn. For this thesis, the gamma service distribution for a land use similar to that of the State Street area was rescaled to the mean delivery times as observed in Chicago.

Confidence intervals and levels were pre-specified in determining the number of simulation runs necessary for the models under each policy. Adjustments were made for the fact that the data is auto-correlated.

In the study area, two types of deliveries were identified: on-street and off-street. The on-street

deliveries were diverted to cross street loading zones. Using the same arrival rate, simulation runs were made for the present curb side deliveries and the proposed cross street deliveries. Each block was simulated separately, and each showed an increase in time to make a delivery under this policy.

The off-street deliveries are made to six east-west alleys in the study area. Generally, three policies were simulated for each alley: (1) present conditions, (2) closure of each alley at State, and (3) time-restricted entry or exit to State for alley access. The arrival rate for a particular alley was used in the simulation of that alley under each policy, and each alley was simulated separately. In almost all cases, an increase in time to make a delivery was observed under the proposed vehicle control policies.

As a way to reduce these increased costs, two types of alternatives were discussed. The first concerned changes in policy to specific blocks or alleys. The second dealt with the construction and operation of a central receiving facility for goods delivery to the mall retailers. The feasibility of these were speculated upon, but they were not simulated.

8.2 Conclusions

The introduction of vehicle control policies to the State Street retail area will result in significant increases in the short run marginal costs of the carriers serving the area. The aggregate cost increase would be over $7,000 per week for the carriers making curb side deliveries, and between $14,000 and $30,000 per week for the alley deliveries, depending upon the policy evaluated. The potential exists for the reduction of these increases by means of various adjustments in the policies, or perhaps through the construction and operation of a central receiving facility for all but the largest retailers. The need exists to confirm the validity of the assumptions made in the models through on-site observation in a systematic manner for an extended period of time. If this is done, and the observations conform to the results of the simulation runs for the present conditions, a strong basis would be made for discussion between the carriers, the retailers, and the city of Chicago concerning a central receiving facility or other method of reducing the expected cost increases.

APPENDICES

APPENDIX A

NOTATION

Queuing Notation

λ = arrival rate

μ = service rate

ρ = utilization factor

M = number of parallel servers

L = Mean number of vehicles in the system

T_a = $1/\lambda$ = mean inter-arrival time

T_s = $1/\mu$ = mean service time

α = shape parameter of the gamma distribution

β = scale parameter of the gamma distribution

Statistical Notation

n = number of observations of waiting time in one run

W_j = the jth observation of waiting time in one run

$\overline{X}$ = the sample mean

$V(\overline{X})$ = variance of the sample mean

$V(X)$ = true variance

s^2 = unbiased estimate of the true variance

μ_x = the true mean

Z = standard normal variate

x_i = $\overline{W}$ = mean of the observations of one run i

N = the number of independent simulation runs

APPENDIX A (continued)

Statistical Notation (continued)

σ^2 = the variance of the process

ξ = damping constant

$V(\overline{W})$= estimate of the true variance, corrected for auto-correlation

α = probability of the sample mean $\overline{X}$ being outside the specific interval about the true mean μ_X

APPENDIX B

This appendix contains the programs used to simulate the on-street and off-street deliveries in the study area. Liberal use was made of comment cards in the programs. The simulation language was GPSS.

1. Present curb side deliveries on State Street
2. Cross-street deliveries
3. Alley #1, Couch, present
4. Alley #1, Couch, time-restricted exit across State
5. Alley #2, Court, present
6. Alley #2, Court, closure at State Street
7. Alley #2, Court, time-restricted exit to State Street
8. Alley #3, Calhoun, present
9. Alley #3, Calhoun, closure at State Street
10. Alley #3, Calhoun, time-restricted exit to State Street
11. Alley #5, Marble, present
12. Alley #5, Marble, time-restricted entry to State Street
13. Alley #6, Quincy, present
14. Alley #6, Quincy, time-restricted entry/exit to State
15. Calculation of the cumulative distribution function for the gamma service times.

```
       BLOCK                                                                       CARD
       NUMBER  *LOC  OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS                  NUMBER
                     RMULT      ,975321,420257                                         1
                     SIMULATE                                                          2
               *     STEP FUNCTION FOR MEAN INTERARRIVAL TIMES, BLOCK NO. 6            3
   1           1     FUNCTION   C1,D5                                                  4
   1           7200,1320/10800,660/21600,1320/28800,1320/32400,60000                   5
               *     EXPONENTIAL INTERARRIVAL TIMES                                    6
   2           2     FUNCTION   RN2,C24                                                7
   2           0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                8
   2           0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                 9
   2           0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                10
   2           0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0             11
               *     GAMMA SERVICE TIMES, A=1.25, B=17.6                              12
               *     CURB SIDE DELIVERIES, MEAN = 22 MINUTES                          13
   3           3     FUNCTION   RN3,C24                                               14
   3           0.0,0.0/0.102,204/0.202,378/0.3,558/0.401,762/0.5,990/                 15
   3           0.579,1200/0.601,1266/0.7,1608/0.745,1800/0.813,2160/0.848,2400        16
   3           0.9,2880/0.92,3138/0.94,3462/0.952,3720/0.965,4074/0.97,4248           17
   3           0.976,4500/0.981,4770/0.986,5118/0.991,5628/0.9959,6600/0.999,7800     18
          1          GENERATE   FN1,FN2,1                                             19
          2          GATE LR    1                                                     20
          3          QUEUE      1,1                                                   21
          4          ENTER      1,1                                                   22
          5          DEPART     1,1                                                   23
          6          ADVANCE    FN3                                                   24
          7          LEAVE      1,1                                                   25
          8          TERMINATE                                                        26
          9          GENERATE   32400                                                 27
         10          LOGIC S    1                                                     28
         11          TEST E     Q1,0                                                  29
         12          TEST E     S1,0                                                  30
         13          TERMINATE  1                                                     31
   1           1     STORAGE    10 LOADING ZONES AVAILABLE                            32
   1           1     QTABLE     1,0,120,75                                            33
                     START      1                                                     34

RELATIVE CLOCK       32400   ABSOLUTE CLOCK       32400
BLOCK COUNTS
BLOCK  CURRENT  TOTAL  BLOCK  CURRENT  TOTAL  BLOCK  CURRENT  TOTAL  BLOCK  CURRENT  TOTAL  BLOCK  CURRENT  TOTAL
   1      0       28     11      0       1
   2      0       28     12      0       1
   3      0       28     13      0       1
   4      0       28
   5      0       28
   6      0       28
   7      0       28
   8      0       28
   9      0        1
  10      0        1
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NORTHWESTERN UNIVERSITY GPSS V/6000                              GPSS V/6000   VER. 1.1 PSR 397       08/20/76  19.42.48.   PAGE    1

      BLOCK                                                                                                      CARD
      NUMBER  *LOC  OPERATION  A,B,C,D,E,F,G,H,I,J       COMMENTS                                                NUMBER
                    RMULT      .975321,420257                                                                       1
                    SIMULATE                                                                                        2
              *     STEP FUNCTION FOR MEAN INTERARRIVAL TIMES, BLOCK NO. 6                                          3
    1         1     FUNCTION   C1,D5                                                                                4
    1         7200,1320/10800,660/21600,1320/28800,1320/32400,60000                                                 5
              *     EXPONENTIAL INTERARRIVAL TIMES                                                                  6
    2         2     FUNCTION   RN2,C24                                                                              7
    2         0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                                              8
    2         0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                                               9
    2         0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                                              10
    2         0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0                                           11
              *     GAMMA SERVICE TIMES, A=1.25, B=19.2 X-STREET LZ                                                12
    3         3     FUNCTION   RN3,C24                                                                             13
    3         0.0,0.0/0.102,222./0.2,408./0.302,612./0.4,828./0.454,960.                                           14
    3         0.582,1320./0.652,1560./0.701,1758./0.781,2160./0.85,2640./0.888,3000.                               15
    3         0.9,3144./0.92,3420./0.94,3786./0.95,4014./0.955,4146./0.966,4500.                                   16
    3         0.973,4800./0.981,5196./0.985,5490./0.991,6132./0.9937,6600./.999,7800.                              17
          1         GENERATE   FN1,FN2,1                                                                           18
          2         GATE LR    1                                                                                   19
          3         QUEUE      1,1                                                                                 20
          4         ENTER      1,1                                                                                 21
          5         DEPART     1,1                                                                                 22
          6         ADVANCE    FN3                                                                                 23
          7         LEAVE      1,1                                                                                 24
          8         TERMINATE                                                                                      25
          9         GENERATE   32400                                                                               26
         10         LOGIC S    1                                                                                   27
         11         TEST E     Q1,0                                                                                28
         12         TEST E     S1,0                                                                                29
         13         TERMINATE  1                                                                                   30
    1         1     STORAGE    2 LOADING ZONES AVAILABLE                                                           31
    1         1     QTABLE     1,0,120,75                                                                          32
                    START      1                                                                                   33


RELATIVE CLOCK       32400    ABSOLUTE CLOCK        32400
BLOCK COUNTS
BLOCK   CURRENT   TOTAL  BLOCK   CURRENT   TOTAL  BLOCK   CURRENT   TOTAL  BLOCK   CURRENT   TOTAL  BLOCK   CURRENT   TOTAL
   1        0       28     11        0        1
   2        0       28     12        0        1
   3        0       28     13        0        1
   4        0       28
   5        0       28
   6        0       28
   7        0       28
   8        0       28
   9        0        1
  10        0        1
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AD-A053 525 NORTHWESTERN UNIV EVANSTON ILL F/G 15/5
THE IMPACTS OF VEHICLE CONTROL POLICIES ON THE SHORT RUN COSTS --ETC(U)
JUN 77 J V MADDEN

UNCLASSIFIED NL

2 OF 2
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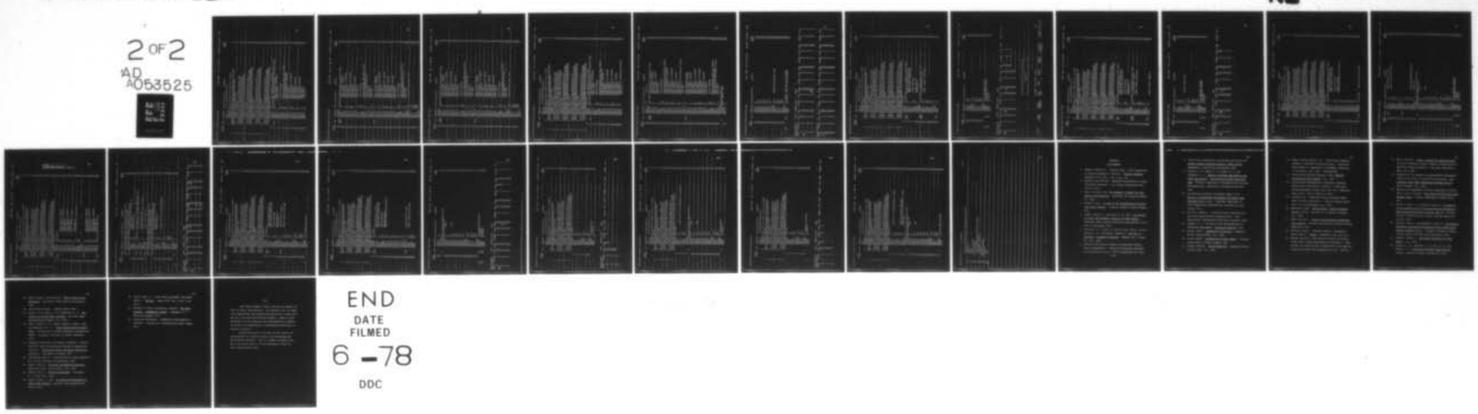

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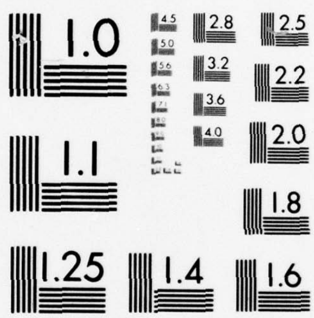

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

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BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J        COMMENTS                                   CARD
                                                                                                NUMBER
               RMULT      .123570,420257,320531,111017                                            1
               SIMULATE                                                                           2
        *      STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 1, COUCH                               3
  1     1      FUNCTION   C1,D11                                                                  4
  1     3600,1800/7200,1800/10800,1800/14400,720/18000,60000/21600,60000                          5
  1     25200,900/28800,720/32400,1800/36000,720/39600,60000                                      6
        *      EXPONENTIAL INTERARRIVAL TIMES                                                     7
  2     2      FUNCTION   RN2,C24                                                                 8
  2     0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                                  9
  2     0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                                   10
  2     0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                                   11
  2     0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0                                12
        *      GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES                                 13
  4     4      FUNCTION   RN3,C24                                                                 14
  4     0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                                    15
  4     0.501,1422/0.630,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                           16
  4     0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                          17
  4     0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                        18
        *      SERVICE TIMES FOR SVR2                                                             19
  5     5      FUNCTION   RN4,C24                                                                 20
  5     0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                                    21
  5     0.501,1422/0.630,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                           22
  5     0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                          23
  5     0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                        24
        *      SERVICE TIMES FOR SVR3                                                             25
  6     6      FUNCTION   RN5,C24                                                                 26
  6     0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                                    27
  6     0.501,1422/0.630,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                           28
  6     0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                          29
  6     0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                        30
     1         GENERATE   FN1,FN2,1                                                               31
     2         GATE LR    7                STOP GENERATION AT 1800 HOURS                          32
     3         TRANSFER   .333,SVR23,SVR1  UNIFORM ALLOCATION OF X#ACTIONS TO SVRS                33
     4  SVR1   QUEUE      1,1              QUEUE FOR ENTRY TO ALLEY                               34
     5         GATE LR    1                BLOCK IF SPACE 1 IS OCCUPIED                           35
     6         LOGIC S    1                OCCUPY SPACE 1                                         36
     7         SEIZE      1                                                                       37
     8         DEPART     1,1              SERVICE COMMENCED                                      38
     9         ADVANCE    FN4                                                                     39
    10         RELEASE    1                SERVICE COMPLETED, SPACE STILL OCCUPIED                40
    11         QUEUE      2,1              QUEUE FOR DEPARTURE FROM ALLEY                         41
    12         GATE LR    21               BLOCK IF SPACE 21 IS OCCUPIED                          42
    13         LOGIC S    21               OCCUPY SPACE 21                                        43
    14         LOGIC R    1                CLEAR SPACE 1                                          44
    15         GATE LR    22               BLOCK IF SPACE 22 IS OCCUPIED                          45
    16         LOGIC S    22               OCCUPY SPACE 22                                        46
    17         LOGIC R    21               CLEAR SPACE 21                                         47
    18         GATE LR    2                BLOCK IF SPACE 2 OCCUPIED                              48
    19         LOGIC S    2                OCCUPY SPACE 2                                         49
    20         LOGIC R    22               CLEAR SPACE 22                                         50
    21         GATE LR    3                BLOCK IF SPACE 3 OCCUPIED                              51
    22         LOGIC S    3                OCCUPY SPACE 3                                         52
    23         LOGIC R    2                CLEAR SPACE 2                                          53
    24         LOGIC R    3                  CLEAR SPACE 3                                        54
    25         DEPART     2,1              LEAVE ALLEY                                            55
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```
BLOCK                                                                    CARD
NUMBER  *LOC    OPERATION  A,B,C,D,E,F,G,H,I,J  COMMENTS                NUMBER
  26            TERMINATE                                                 56
  27    SVR23   TRANSFER   .5,SVR3,SVR2 UNIFORM ALLOC OF X*ACTIONS TO SVRS  57
  28    SVR2    QUEUE      1,1          QUEUE FOR ENTRY TO ALLEY          58
  29            GATE LR    1            BLOCK IF SPACE 1 OCCUPIED         59
  30            LOGIC S    1            OCCUPY SPACE 1                    60
  31            GATE LR    21           BLOCK IF SPACE 21 IS OCCUPIED     61
  32            LOGIC S    21           OCCUPY SPACE 21                   62
  33            LOGIC R    1            CLEAR SPACE 1                     63
  34            GATE LR    22           BLOCK IF SPACE 22 IS OCCUPIED     64
  35            LOGIC S    22           OCCUPY SPACE 22                   65
  36            LOGIC R    21           CLEAR SPACE 21                    66
  37            GATE LR    2            BLOCK IF SPACE 2 OCCUPIED         67
  38            LOGIC S    2            OCCUPY SPACE 2                    68
  39            LOGIC R    22           CLEAR SPACE 22                    69
  40            SEIZE      2                                              70
  41            DEPART     1,1          SERVICE COMMENCED                 71
  42            ADVANCE    FN5                                            72
  43            RELEASE    2            SERVICE COMPLETED, SPACE STILL OCCUPIED  73
  44            QUEUE      2,1          QUEUE FOR DEPARTURE FROM ALLEY    74
  45            GATE LR    3            BLOCK IF SPACE 3 OCCUPIED         75
  46            LOGIC S    3            OCCUPY SPACE 3                    76
  47            LOGIC R    2            CLEAR SPACE 2                     77
  48            LOGIC R    3            CLEAR SPACE 3                     78
  49            DEPART     2,1          LEAVE ALLEY                       79
  50            TERMINATE                                                 80
  51    SVR3    QUEUE      1,1          QUEUE FOR ENTRY TO ALLEY          81
  52            GATE LR    1            BLOCK IF SPACE 1 OCCUPIED         82
  53            LOGIC S    1            OCCUPY SPACE 1                    83
  54            GATE LR    21           BLOCK IF SPACE 21 IS OCCUPIED     84
  55            LOGIC S    21           OCCUPY SPACE 21                   85
  56            LOGIC R    1            CLEAR SPACE 1                     86
  57            GATE LR    22           BLOCK IF SPACE 22 IS OCCUPIED     87
  58            LOGIC S    22           OCCUPY SPACE 22                   88
  59            LOGIC R    21           CLEAR SPACE 21                    89
  60            GATE LR    2            BLOCK IF SPACE 2 OCCUPIED         90
  61            LOGIC S    2            OCCUPY SPACE 2                    91
  62            LOGIC R    22           CLEAR SPACE 22                    92
  63            GATE LR    3            BLOCK IF SPACE 3 OCCUPIED         93
  64            LOGIC S    3            OCCUPY SPACE 3                    94
  65            LOGIC R    2            CLEAR SPACE 2                     95
  66            SEIZE      3                                              96
  67            DEPART     1,1          SERVICE COMMENCED                 97
  68            ADVANCE    FN6                                            98
  69            RELEASE    3            SERVICE COMPLETED, SPACE STILL OCCUPIED  99
  70            QUEUE      2,1          QUEUE FOR DEPARTURE FROM ALLEY   100
  71            LOGIC R    3            CLEAR SPACE 3                    101
  72            DEPART     2,1          LEAVE ALLEY                      102
  73            TERMINATE                                                103
  74            GENERATE   36000        0800*1800 HRS DELIVERY TIMES     104
  75            LOGIC S    7                                             105
  76            TEST E     Q1,0                                          106
  77            TEST E     F1,0                                          107
  78            TEST E     F2,0                                          108
  79            TEST E     F3,0                                          109
  80            TEST E     Q2,0                                          110
                TERMINATE 1
```

BLOCK NUMBER	*LOC	OPERATION	A,B,C,D,E,F,G,H,I,J	COMMENTS	CARD NUMBER
26		TERMINATE			56
27	SVR23	TRANSFER	.5,SVR3,SVR2	UNIFORM ALLOC OF X*ACTIONS TO SVRS	57
28	SVR2	QUEUE	1,1	QUEUE FOR ENTRY TO ALLEY	58
29		GATE LR	1	BLOCK IF SPACE 1 OCCUPIED	59
30		LOGIC S	1	OCCUPY SPACE 1	60
31		GATE LR	21	BLOCK IF SPACE 21 IS OCCUPIED	61
32		LOGIC S	21	OCCUPY SPACE 21	62
33		LOGIC R	1	CLEAR SPACE 1	63
34		GATE LR	22	BLOCK IF SPACE 22 IS OCCUPIED	64
35		LOGIC S	22	OCCUPY SPACE 22	65
36		LOGIC R	21	CLEAR SPACE 21	66
37		GATE LR	2	BLOCK IF SPACE 2 OCCUPIED	67
38		LOGIC S	2	OCCUPY SPACE 2	68
39		LOGIC R	22	CLEAR SPACE 22	69
40		SEIZE	2		70
41		DEPART	1,1	SERVICE COMMENCED	71
42		ADVANCE	FN5		72
43		RELEASE	2	SERVICE COMPLETED, SPACE STILL OCCUPIED	73
44		QUEUE	2,1	QUEUE FOR DEPARTURE FROM ALLEY	74
45		GATE LR	3	BLOCK IF SPACE 3 OCCUPIED.	75
46		LOGIC S	3	OCCUPY SPACE 3	76
47		LOGIC R	2	CLEAR SPACE 2	77
48		LOGIC R	3	CLEAR SPACE 3	78
49		DEPART	2,1	LEAVE ALLEY	79
50		TERMINATE			80
51	SVR3	QUEUE	1,1	QUEUE FOR ENTRY TO ALLEY	81
52		GATE LR	1	BLOCK IF SPACE 1 OCCUPIED	82
53		LOGIC S	1	OCCUPY SPACE 1	83
54		GATE LR	21	BLOCK IF SPACE 21 IS OCCUPIED	84
55		LOGIC S	21	OCCUPY SPACE 21	85
56		LOGIC R	1	CLEAR SPACE 1	86
57		GATE LR	22	BLOCK IF SPACE 22 IS OCCUPIED	87
58		LOGIC S	22	OCCUPY SPACE 22	88
59		LOGIC R	21	CLEAR SPACE 21	89
60		GATE LR	2	BLOCK IF SPACE 2 OCCUPIED	90
61		LOGIC S	2	OCCUPY SPACE 2	91
62		LOGIC R	22	CLEAR SPACE 22	92
63		GATE LR	3	BLOCK IF SPACE 3 OCCUPIED	93
64		LOGIC S	3	OCCUPY SPACE 3	94
65		LOGIC R	2	CLEAR SPACE 2	95
66		SEIZE	3		96
67		DEPART	1,1	SERVICE COMMENCED	97
68		ADVANCE	FN6		98
69		RELEASE	3	SERVICE COMPLETED, SPACE STILL OCCUPIED	99
70		QUEUE	2,1	QUEUE FOR DEPARTURE FROM ALLEY	100
71		LOGIC R	3	CLEAR SPACE 3	101
72		DEPART	2,1	LEAVE ALLEY	102
73		TERMINATE			103
74		GENERATE	36000	0800*1800 HRS DELIVERY TIMES	104
75		LOGIC S	7		105
76		TEST F	Q1,0		106
77		TEST E	F1,0		107
78		TEST F	F2,0		108
79		TEST E	F3,0		109
80		TEST E	Q2,0		110
		TERMINATE	1		
		START	1		

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       BLOCK                                                                                        CARD
       NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS                                 NUMBER
                      RMULT      ,123579,420257,320531,111017                                         1
                      SIMULATE                                                                        2
               *      STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 1, COUCH                            3
         1     1      FUNCTION   C1,D11                                                               4
         1     3600,1800/7200,1800/10800,1800/14400,720/18000,60000/21600,60000                       5
         1     25200,900/28800,720/32400,1800/36000,720/39600,60000                                   6
               *      EXPONENTIAL INTERARRIVAL TIMES                                                  7
         2     2      FUNCTION   RN2,C24                                                              8
         2     0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                               9
         2     0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                               10
         2     0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                               11
         2     0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0                            12
               *      GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES                             13
         4     4      FUNCTION   RN3,C24                                                             14
         4     0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                                15
         4     0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                       16
         4     0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                      17
         4     0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                    18
               *      SERVICE TIMES FOR SVR2                                                         19
         5     5      FUNCTION   RN4,C24                                                             20
         5     0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                                21
         5     0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                       22
         5     0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                      23
         5     0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                    24
               *      SERVICE TIMES FOR SVR3                                                         25
         6     6      FUNCTION   RN5,C24                                                             26
         6     0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                                27
         6     0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                       28
         6     0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                      29
         6     0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                    30
           1          GENERATE   FN1,FN2,1                                                           31
           2          GATE LR    7              STOP GENERATION AT 1800 HOURS                        32
           3          TRANSFER   .333,SVR23,SVR1  UNIFORM ALLOCATION OF X#ACTIONS TO SVRS            33
           4   SVR1   QUEUE      1,1            QUEUE FOR ENTRY TO ALLEY                             34
           5          GATE LR    1              BLOCK IF SPACE 1 IS OCCUPIED                         35
           6          LOGIC S    1              OCCUPY SPACE 1                                       36
           7          SEIZE      1                                                                   37
           8          DEPART     1,1            SERVICE COMMENCED                                    38
           9          ADVANCE    FN4                                                                 39
          10          RELEASE    1              SERVICE COMPLETED, SPACE STILL OCCUPIED              40
          11          QUEUE      2,1            QUEUE FOR DEPARTURE FROM ALLEY                       41
          12          GATE LR    2              BLOCK IF SPACE 2 OCCUPIED                            42
          13          LOGIC S    2              OCCUPY SPACE 2                                       43
          14          LOGIC R    1              CLEAR SPACE 1                                        44
          15          GATE LR    21             BLOCK IF SPACE 21 IS OCCUPIED                        45
          16          LOGIC S    21             OCCUPY SPACE 21                                      46
          17          LOGIC R    2              CLEAR SPACE 2                                        47
          18          GATE LR    22             BLOCK IF SPACE 22 IS OCCUPIED                        48
          19          LOGIC S    22             OCCUPY SPACE 22                                      49
          20          LOGIC R    21             CLEAR SPACE 21                                       50
          21          GATE LR    3              BLOCK IF SPACE 3 OCCUPIED                            51
          22          LOGIC S    3              OCCUPY SPACE 3                                       52
          23          LOGIC R    22             CLEAR SPACE 22                                       53
          24          GATE LR    4              BLOCK EXIT IF TIME RESTRICTION IN EFFECT             54
          25          LOGIC R    3               CLEAR SPACE 3                                       55
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  BLOCK
 NUMBER  *LOC    OPERATION  A,B,C,D,E,F,G,H,I,J       COMMENTS                                  CARD
                                                                                               NUMBER
   26            DEPART     2,1          LEAVE ALLEY                                              56
   27            TERMINATE                                                                        57
   28    SVR23   TRANSFER   .5,SVR3,SVR2 UNIFORM ALLOC OF X*ACTIONS TO SVRS                       58
   29    SVR2    QUEUE      1,1          QUEUE FOR ENTRY TO ALLEY                                 59
   30            GATE LR    1            BLOCK IF SPACE 1 OCCUPIED                                60
   31            LOGIC S    1            OCCUPY SPACE 1                                           61
   32            GATE LR    2            BLOCK IF SPACE 2 OCCUPIED                                62
   33            LOGIC S    2            OCCUPY SPACE 2                                           63
   34            LOGIC R    1            CLEAR SPACE 1                                            64
   35            SEIZE      2                                                                     65
   36            DEPART     1,1          SERVICE COMMENCED                                        66
   37            ADVANCE    FN5                                                                   67
   38            RELEASE    2            SERVICE COMPLETED, SPACE STILL OCCUPIED                  68
   39            QUEUE      2,1          QUEUE FOR DEPARTURE FROM ALLEY                           69
   40            GATE LR    21           BLOCK IF SPACE 21 IS OCCUPIED                            70
   41            LOGIC S    21           OCCUPY SPACE 21                                          71
   42            LOGIC R    2            CLEAR SPACE 2                                            72
   43            GATE LR    22           BLOCK IF SPACE 22 IS OCCUPIED                            73
   44            LOGIC S    22           OCCUPY SPACE 22                                          74
   45            LOGIC R    21           CLEAR SPACE 21                                           75
   46            GATE LR    3            BLOCK IF SPACE 3 OCCUPIED                                76
   47            LOGIC S    3            OCCUPY SPACE 3                                           77
   48            LOGIC R    22           CLEAR SPACE 22                                           78
   49            GATE LR    4            BLOCK EXIT IF TIME RESTRICTION IN EFFECT                 79
   50            LOGIC R    3            CLEAR SPACE 3                                            80
   51            DEPART     2,1          LEAVE ALLEY                                              81
   52            TERMINATE                                                                        82
   53    SVR3    QUEUE      1,1          QUEUE FOR ENTRY TO ALLEY                                 83
   54            GATE LR    1            BLOCK IF SPACE 1 OCCUPIED                                84
   55            LOGIC S    1            OCCUPY SPACE 1                                           85
   56            GATE LR    2            BLOCK IF SPACE 2 OCCUPIED                                86
   57            LOGIC S    2            OCCUPY SPACE 2                                           87
   58            LOGIC R    1            CLEAR SPACE 1                                            88
   59            GATE LR    21           BLOCK IF SPACE 21 IS OCCUPIED                            89
   60            LOGIC S    21           OCCUPY SPACE 21                                          90
   61            LOGIC R    2            CLEAR SPACE 2                                            91
   62            GATE LR    22           BLOCK IF SPACE 22 IS OCCUPIED                            92
   63            LOGIC S    22           OCCUPY SPACE 22                                          93
   64            LOGIC R    21           CLEAR SPACE 21                                           94
   65            GATE LR    3            BLOCK IF SPACE 3 OCCUPIED                                95
   66            LOGIC S    3            OCCUPY SPACE 3                                           96
   67            LOGIC R    22           CLEAR SPACE 22                                           97
   68            SEIZE      3                                                                     98
   69            DEPART     1,1          SERVICE COMMENCED                                        99
   70            ADVANCE    FN6                                                                  100
   71            RELEASE    3            SERVICE COMPLETED, SPACE STILL OCCUPIED                 101
   72            QUEUE      2,1          QUEUE FOR DEPARTURE FROM ALLEY                          102
   73            GATE LR    4            BLOCK EXIT IF TIME RESTRICTION IN EFFECT                103
   74            LOGIC R    3            CLEAR SPACE 3                                           104
   75            DEPART     2,1          LEAVE ALLEY                                             105
   76            TERMINATE                                                                       106
         *       TIME RESTRICTIONS FOR ALLEY EXIT                                                107
         *       LS SET = CLOSED, LS RESET = OPEN                                                108
   77            GENERATE   1                                                                    109
   78            GATE LR    41                                                                   110
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BLOCK NUMBER	*LOC	OPERATION	A,B,C,D,E,F,G,H,I,J	COMMENTS	CARD NUMBER
79		LOGIC S	41		111
80		LOGIC S	4		112
81		ADVANCE	5400		113
82		LOGIC R	4		114
83		ADVANCE	7200		115
84		LOGIC S	4		116
85		ADVANCE	7200		117
86		LOGIC R	4		118
87		ADVANCE	7200		119
88		LOGIC S	4		120
89		ADVANCE	7200		121
90		LOGIC R	4		122
91		TERMINATE			123
92		GENERATE	36000	0800*1800 HRS DELIVERY TIMES	124
93		LOGIC S	7		125
94		TEST E	Q1,0		126
95		TEST E	F1,0		127
96		TEST E	F2,0		128
97		TEST E	F3,0		129
98		TEST E	Q2,0		130
99		TERMINATE	1		131
10	10	QTABLE	1,0,120,46	2 MIN INC, 1*1/2 HR SPREAD	132
20	20	QTABLE	2,0,120,46	2 MIN INC, 1*1/2 HR SPREAD	133
		START	1		134

RELATIVE CLOCK 36000 ABSOLUTE CLOCK 36000

BLOCK COUNTS

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
1	0	15	11	0	5	21	0	5	31	0	4	41	0	4
2	0	15	12	0	5	22	0	5	32	0	4	42	0	4
3	0	15	13	0	5	23	0	5	33	0	4	43	0	4
SVR1	0	5	14	0	5	24	0	5	34	0	4	44	0	4
5	0	5	15	0	5	25	0	5	35	0	4	45	0	4
6	0	5	16	0	5	26	0	5	36	0	4	46	0	4
7	0	5	17	0	5	27	0	5	37	0	4	47	0	4
8	0	5	18	0	5	SVR23	0	10	38	0	4	48	0	4
9	0	5	19	0	5	SVR2	0	4	39	0	4	49	0	4
10	0	5	20	0	5	30	0	4	40	0	4	50	0	4

BLOCK COUNTS

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
51	0	4	61	0	6	71	0	6	81	0	1	91	0	1
52	0	4	62	0	6	72	0	6	82	0	1	92	0	1
SVR3	0	6	63	0	6	73	0	6	83	0	1	93	0	1
54	0	6	64	0	6	74	0	6	84	0	1	94	0	1
55	0	6	65	0	6	75	0	6	85	0	1	95	0	1
56	0	6	66	0	6	76	0	6	86	0	1	96	0	1
57	0	6	67	0	6	77	1	1	87	0	1	97	0	1
58	0	6	68	0	6	78	0	1	88	0	1	98	0	1
59	0	6	69	0	6	79	0	1	89	0	1	99	0	1
60	0	6	70	0	6	80	0	1	90	0	1			

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         BLOCK                                                                                    CARD
         NUMBER  *LOC    OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS                             NUMBER
                         RMULT      ,975321,420257,320531,111017                                      1
                         SIMULATE                                                                     2
                 *       STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 2, COURT                         3
    1            1       FUNCTION   C1,D11                                                            4
    1            3600,600/7200,900/10800,400/14400,400/18000,900/21600,1200                           5
    1            25200,900/28800,1200/32400,900/36000,3600/39600,60000                                6
                 *       EXPONENTIAL INTERARRIVAL TIMES                                               7
    2            2       FUNCTION   RN2,C24                                                           8
    2            0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                             9
    2            0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                             10
    2            0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                             11
    2            0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0                          12
                 *       GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES                          13
    4            4       FUNCTION   RN3,C24                                                          14
    4            0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                              15
    4            0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                     16
    4            0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                    17
    4            0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                  18
                 *       SERVICE TIMES FOR SRV2                                                      19
    5            5       FUNCTION   RN4,C24                                                          20
    5            0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                              21
    5            0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                     22
    5            0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                    23
    5            0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                  24
                 *       SERVICE TIMES FOR SRV3                                                      25
    6            6       FUNCTION   RN5,C24                                                          26
    6            0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                              27
    6            0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                     28
    6            0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                    29
    6            0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                  30
             1           GENERATE   FN1,FN2,1                                                        31
             2           GATE LR    7                                                                32
             3   DEC1    TRANSFER   .2,SVR23,SVR1  1/5 OF XACTIONS TO LOADING DOOR                   33
             4   SVR1    QUEUE      1,1            QUEUE FOR ENTRY TO ALLEY                          34
             5           GATE LR    1              BLOCK IF LOADING DOOR IN USE                      35
             6           LOGIC S    1              OCCUPY SPACE AT LOADING DOOR                      36
             7           SEIZE      1                                                                37
             8           DEPART     1,1            SERVICE COMMENCED                                 38
             9           ADVANCE    FN4                                                              39
            10           RELEASE    1              SERVICE COMPLETED                                 40
            11           LOGIC R    1              CLEAR SPACE 1                                     41
            12           TERMINATE                                                                   42
            13   SVR23   TRANSFER   .5,SVR3,SVR2      UNIFORM DISTN TO DOCK-PAIRS                    43
            14   SVR2    QUEUE      1,1            QUEUE FOR ENTRY TO ALLEY                          44
            15           GATE LR    1                                                                45
            16           ENTER      2,1            OCCUPY 1 SPACE AT WEST DOCKS                      46
            17           DEPART     1,1                                                              47
            18           ADVANCE    FN5                                                              48
            19           LEAVE      2,1                                                              49
            20           QUEUE      2,1                                                              50
            21           GATE LR    1                                                                51
            22           DEPART     2,1                                                              52
            23           TERMINATE                                                                   53
            24   SVR3    QUEUE      1,1                                                              54
            25           ENTER      3,1                                                              55
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	BLOCK NUMBER	*LOC	OPERATION	A,B,C,D,E,F,G,H,I,J	COMMENTS	CARD NUMBER
	26		DEPART	1,1		56
	27		ADVANCE	FN6		57
	28		LEAVE	3,1		58
	29		TERMINATE			59
	30		GENERATE	36000		60
	31		LOGIC S	7		61
	32		TEST E	Q1,0		62
	33		TEST E	F1,0		63
	34		TEST E	S2,0		64
	35		TEST E	S3,0		65
	36		TEST E	Q2,0		66
	37		TERMINATE	1		67
2		2	STORAGE	2 DOCK POSITIONS AVAILABLE		68
3		3	STORAGE	2 DOCK POSITIONS AVAILABLE		69
10		10	QTABLE	1,0,300,75		70
20		20	QTABLE	2,0,300,75		71
			START	1		72

RELATIVE CLOCK 36282 ABSOLUTE CLOCK 36282

BLOCK COUNTS

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
1	0	49	11	0	11	21	0	22	31	0	1			
2	0	49	12	0	11	22	0	22	32	0	1			
DEC1	0	49	SVR23	0	38	23	0	22	33	0	1			
SVR1	0	11	SVR2	0	22	SVR3	0	16	34	0	1			
5	0	11	15	0	22	25	0	16	35	0	1			
6	0	11	16	0	22	26	0	16	36	0	1			
7	0	11	17	0	22	27	0	16	37	0	1			
8	0	11	18	0	22	28	0	16						
9	0	11	19	0	22	29	0	16						
10	0	11	20	0	22	30	0	1						

FACILITIES

- AVERAGE UTILIZATION DURING -

FACILITY	NUMBER ENTRIES	AVERAGE TIME/TRAN	TOTAL TIME	AVAIL. TIME	UNAVAIL. TIME	CURRENT STATUS	PERCENT AVAILABILITY	TRANSACTION NUMBER SEIZING	PREEMPTING
1	11	1657.636	0.503			A	100.000		

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      BLOCK                                                                        CARD
      NUMBER *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS                   NUMBER
                    RMULT      ,975321,420257,320531,111017                            1
                    SIMULATE                                                           2
              *     STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 2, COURT               3
   1          1     FUNCTION   C1,D11                                                  4
   1          3600,600/7200,900/10800,400/14400,400/18000,900/21600,1200               5
   1          25200,900/28800,1200/32400,900/36000,3600/39600,60000                    6
              *     EXPONENTIAL INTERARRIVAL TIMES                                     7
   2          2     FUNCTION   RN2,C24                                                 8
   2          0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                 9
   2          0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                 10
   2          0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                 11
   2          0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0              12
              *     GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES                13
   4          4     FUNCTION   RN3,C24                                                14
   4          0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                  15
   4          0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000         16
   4          0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112        17
   4          0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800      18
              *     SERVICE TIMES FOR SRV2                                            19
   5          5     FUNCTION   RN4,C24                                                20
   5          0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                  21
   5          0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000         22
   5          0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112        23
   5          0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800      24
              *     SERVICE TIMES FOR SRV3                                            25
   6          6     FUNCTION   RN5,C24                                                26
   6          0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                  27
   6          0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000         28
   6          0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112        29
   6          0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800      30
          1         GENERATE   FN1,FN2,1                                              31
          2         GATE LR    7                                                      32
          3   DEC1  TRANSFER   .2,SVR23,SVR1  1/5 OF XACTIONS TO LOADING DOOR         33
          4   SVR1  QUEUE      1,1            QUEUE FOR ENTRY TO ALLEY                34
          5         GATE LR    1              BLOCK IF LOADING DOOR IN USE            35
          6         LOGIC S    1              OCCUPY SPACE AT LOADING DOOR            36
          7         SEIZE      1                                                      37
          8         DEPART     1,1            SERVICE COMMENCED                       38
          9         ADVANCE    FN4                                                    39
         10         RELEASE    1              SERVICE COMPLETED                       40
         11         LOGIC R    1              CLEAR SPACE 1                           41
         12         TERMINATE                                                         42
         13   SVR23 TRANSFER   .5,SVR3,SVR2     UNIFORM DISTN TO DOCK PAIRS           43
         14   SVR2  QUEUE      1,1            QUEUE FOR ENTRY TO ALLEY                44
         15         GATE LR    1                                                      45
         16         ENTER      2,1            OCCUPY 1 SPACE AT WEST DOCKS            46
         17         DEPART     1,1                                                    47
         18         ADVANCE    FN5                                                    48
         19         LEAVE      2,1                                                    49
         20         QUEUE      2,1                                                    50
         21         GATE LR    1                                                      51
         22         DEPART     2,1                                                    52
         23         TERMINATE                                                         53
         24   SVR3  QUEUE      1,1                                                    54
         25         GATE LR    1              BLOCK IF SPACE 1 OCCUPIED               55
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       BLOCK                                                                                    CARD
       NUMBER   *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J        COMMENTS                           NUMBER
         26            ENTER      3,1                                                             56
         27            DEPART     1,1                                                             57
         28            ADVANCE    FN6                                                             58
         29            LEAVE      3,1                                                             59
         30            QUEUE      2,1                                                             60
         31            GATE LR    1              BLOCK IF DOOR IN USE                             61
         32            DEPART     2,1                                                             62
         33            TERMINATE                                                                  63
         34            GENERATE   36000                                                           64
         35            LOGIC S    7                                                               65
         36            TEST E     Q1,0                                                            66
         37            TEST E     F1,0                                                            67
         38            TEST E     S2,0                                                            68
         39            TEST E     S3,0                                                            69
         40            TEST E     Q2,0                                                            70
         41            TERMINATE  1                                                               71
    2             2    STORAGE    2 DOCK POSITIONS AVAILABLE                                      72
    3             3    STORAGE    2 DOCK POSITIONS AVAILABLE                                      73
   10            10    QTABLE     1,0,300,75                                                      74
   20            20    QTABLE     2,0,300,75                                                      75
                       START      1                                                               76


RELATIVE CLOCK      36282   ABSOLUTE CLOCK      36282
BLOCK COUNTS
BLOCK     CURRENT   TOTAL  BLOCK     CURRENT   TOTAL  BLOCK     CURRENT   TOTAL  BLOCK     CURRENT   TOTAL  BLOCK     CURRENT   TOTAL
    1           0      49     11           0      11     21           0      22     31           0      16     41           0       1
    2           0      49     12           0      11     22           0      22     32           0      16
DEC1            0      49  SVR23           0      38     23           0      22     33           0      16
SVR1            0      11  SVR2            0      22  SVR3            0      16     34           0       1
    5           0      11     15           0      22     25           0      16     35           0       1
    6           0      11     16           0      22     26           0      16     36           0       1
    7           0      11     17           0      22     27           0      16     37           0       1
    8           0      11     18           0      22     28           0      16     38           0       1
    9           0      11     19           0      22     29           0      16     39           0       1
   10           0      11     20           0      22     30           0      16     40           0       1
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BLOCK                                                                                          CARD
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J        COMMENTS                                 NUMBER

               RMULT      ,975321,420257,320531,111017                                            1
               SIMULATE                                                                           2
         *     STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 2, COURT                               3
  1      1     FUNCTION   C1,D11                                                                  4
  1      3600,600/7200,900/10800,400/14400,400/18000,900/21600,1200                               5
  1      25200,900/28800,1200/32400,900/36000,3600/39600,60000                                    6
         *     EXPONENTIAL INTERARRIVAL TIMES                                                     7
  2      2     FUNCTION   RN2,C24                                                                 8
  2      0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                                 9
  2      0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                                 10
  2      0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                                 11
  2      0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0                              12
         *     GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES                                13
  4      4     FUNCTION   RN3,C24                                                                14
  4      0.0,0.0/0.023,120/0.1,349/0.202,606/0.3,852/0.401,1122                                  15
  4      0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                         16
  4      0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                        17
  4      0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                      18
         *     SERVICE TIMES FOR SRV2                                                            19
  5      5     FUNCTION   RN4,C24                                                                20
  5      0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                                  21
  5      0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                         22
  5      0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                        23
  5      0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                      24
         *     SERVICE TIMES FOR SRV3                                                            25
  6      6     FUNCTION   RN5,C24                                                                26
  6      0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                                  27
  6      0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                         28
  6      0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                        29
  6      0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9382,6600/0.999,7800                      30
        1      GENERATE   FN1,FN2,1                                                              31
        2      GATE LR    7                                                                      32
        3  DEC1  TRANSFER .2,SVR23,SVR1  1/5 OF XACTIONS TO LOADING DOOR                         33
        4  SVR1  QUEUE    1,1            QUEUE FOR ENTRY TO ALLEY                                34
        5      GATE LR    1              BLOCK IF LOADING DOOR IN USE                            35
        6      LOGIC S    1              OCCUPY SPACE AT LOADING DOOR                            36
        7      SEIZE      1                                                                      37
        8      DEPART     1,1            SERVICE COMMENCED                                       38
        9      ADVANCE    FN4                                                                    39
       10      RELEASE    1              SERVICE COMPLETED                                       40
       11      QUEUE      3,1            QUEUE FOR DEPARTURE FROM STATE END                      41
       12      GATE LR    11                                                                     42
       13      LOGIC S    11                                                                     43
       14      LOGIC R    1                                                                      44
       15      GATE LR    12                                                                     45
       16      LOGIC S    12                                                                     46
       17      LOGIC R    11                                                                     47
       18      GATE LR    13                                                                     48
       19      LOGIC S    13                                                                     49
       20      LOGIC R    12                                                                     50
       21      GATE LR    4                                                                      51
       22      LOGIC R    13                                                                     52
       23      DEPART     3,1                                                                    53
       24      TERMINATE                                                                         54
       25  SVR23 TRANSFER .5,SVR3,SVR2   UNIFORM DISTN TO DOCK PAIRS                             55
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  BLOCK                                                                     CARD
  NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J       COMMENTS              NUMBER
    26    SVR2   QUEUE      1,1          QUEUE FOR ENTRY TO ALLEY              56
    27           GATE LR    1                                                  57
    28           ENTER      2,1          OCCUPY 1 SPACE AT WEST DOCKS          58
    29           DEPART     1,1                                                59
    30           ADVANCE    FN5                                                60
    31           LEAVE      2,1                                                61
    32           QUEUE      2,1                                                62
    33           GATE LR    1                                                  63
    34           DEPART     2,1                                                64
    35           TERMINATE                                                     65
    36    SVR3   QUEUE      1,1                                                66
    37           GATE LR    1                                                  67
    38           ENTER      3,1                                                68
    39           DEPART     1,1                                                69
    40           ADVANCE    FN6                                                70
    41           LEAVE      3,1                                                71
    42           QUEUE      2,1          QUEUE FOR DEPARTURE FROM ALLEY        72
    43           GATE LR    1                                                  73
    44           DEPART     2,1          LEAVE ALLEY                           74
    45           TERMINATE                                                     75
           *     TIME RESTRICTIONS FOR ALLEY ENTRANCE OR EXIT                  76
           *     LS SET = CLOSED, LS RESET = OPEN                              77
    46           GENERATE   1            0800                                  78
    47           GATE LR    41                                                 79
    48           LOGIC S    41                                                 80
    49           LOGIC S    4                                                  81
    50           ADVANCE    5400         0930                                  82
    51           LOGIC R    4                                                  83
    52           ADVANCE    7200                                               84
    53           LOGIC S    4                                                  85
    54           ADVANCE    7200                                               86
    55           LOGIC R    4                                                  87
    56           ADVANCE    7200                                               88
    57           LOGIC S    4                                                  89
    58           ADVANCE    7200                                               90
    59           LOGIC R    4                                                  91
    60           TERMINATE                                                     92
    61           GENERATE   36000                                              93
    62           LOGIC S    7                                                  94
    63           TEST E     Q1,0                                               95
    64           TEST E     F1,0                                               96
    65           TEST E     S2,0                                               97
    66           TEST E     S3,0                                               98
    67           TEST E     Q2,0                                               99
    68           TEST E     C3,0                                              100
    69           TERMINATE  1                                                 101
     2      2    STORAGE    2 DOCK POSITIONS AVAILABLE                        102
     3      3    STORAGE    2 DOCK POSITIONS AVAILABLE                        103
    10     10    QTABLE     1,0,300,75                                        104
    20     20    QTABLE     2,0,300,75                                        105
    30     30    QTABLE     3,0,120,75                                        106
                 START      1                                                 107
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BEST AVAILABLE COPY

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 BLOCK
 NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS                                   CARD
                                                                                               NUMBER
                RMULT      .975321,420289,320531,111017                                          1
                SIMULATE                                                                         2
         *      STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 3, CALHOUN                           3
   1     1      FUNCTION   C1,D11                                                                4
   1   3600,225/7200,300/10800,720/14400,514/18000,720/21900,600                                 5
   1   25200,1800/28800,277/32400,1800/36000,60000/39600,60000                                   6
         *      EXPONENTIAL INTERARRIVAL TIMES                                                   7
   2     2      FUNCTION   RN2,C24                                                               8
   2   0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                                  9
   2   0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                                  10
   2   0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                                  11
   2   0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0                               12
         *      GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES                              13
   4     4      FUNCTION   RN3,C24                                                              14
   4   0.0,0.0/0.023,120/0.1,349/0.202,606/0.3,852/0.401,1122                                   15
   4   0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                          16
   4   0.867,3360/0.966,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                         17
   4   0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                       18
         *      SERVICE TIMES FOR SRV2                                                          19
   5     5      FUNCTION   RN4,C24                                                              20
   5   0.0,0.0/0.023,120/0.1,349/0.202,606/0.3,852/0.401,1122                                   21
   5   0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                          22
   5   0.867,3360/0.996,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                         23
   5   0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                       24
         1      GENERATE   FN1,FN2,1                                                            25
         2      GATE LR    7                                                                    26
         3 DEC1 TRANSFER   .3,SVR23,SVR1                                                        27
         4 SVR1 QUEUE      1,1                                                                  28
         5      GATE LR    11             BLOCK IF SPACE 11 OCCUPIED                            29
         6      LOGIC S    11             OCCUPY SPACE 11                                       30
         7      GATE LR    12             BLOCK IF SPACE 12 OCCUPIED                            31
         8      LOGIC S    12             OCCUPY SPACE 12                                       32
         9      LOGIC R    11             CLEAR SPACE 11                                        33
        10      GATE LR    13             BLOCK IF SPACE 13 OCCUPIED                            34
        11      LOGIC S    13             OCCUPY SPACE 13                                       35
        12      LOGIC R    12             CLEAR SPACE 12                                        36
        13      GATE LR    1              BLOCK IF SPACE 1 OCCUPIED                             37
        14      LOGIC S    1                                                                    38
        15      LOGIC R    13             CLEAR SPACE 13                                        39
        16      SEIZE      1              OCCUPY SPACE AT LOADING DOOR                          40
        17      DEPART     1,1                                                                  41
        18      ADVANCE    FN4                                                                  42
        19      RELEASE    1                                                                    43
        20      LOGIC R    1                                                                    44
        21      TERMINATE                                                                       45
        22 SVR23 QUEUE     1,1                                                                  46
        23      GATE LR    11             BLOCK IF SPACE 11 OCCUPIED                            47
        24      LOGIC S    11             OCCUPY SPACE 11                                       48
        25      GATE LR    12             BLOCK IF SPACE 12 OCCUPIED                            49
        26      LOGIC S    12             OCCUPY SPACE 12                                       50
        27      LOGIC R    11             CLEAR SPACE 11                                        51
        28      GATE LR    13             BLOCK IF SPACE 13 OCCUPIED                            52
        29      LOGIC S    13             OCCUPY SPACE 13                                       53
        30      LOGIC R    12             CLEAR SPACE 12                                        54
        31 SVR3 GATE SNF   3,SVR2 TRY SRV2 IF SVR3 IS FULL                                      55
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  BLOCK                                                                      CARD
  NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J      COMMENTS                NUMBER
                 ***************************************************          56
                 *       NOTE THAT SERVICE TIME IN THIS MODEL INCLUDES  *     57
                 *       THE TIME IN THE QUEUE FOR DEPARTURE FROM ALLEY *     58
                 ***************************************************          59
     32          ENTER      3,1            OCCUPY 1 SPACE AT EAST LOADING DOCK 60
     33          LOGIC R    13             CLEAR SPACE 13                      61
     34          DEPART     1,1            SERVICE COMMENCED                   62
     35          ADVANCE    FN5                                                63
     36   WRWAY  TEST E     Q1,0,RTWAY     EXIT WRONG WAY IF POSSIBLE, RIGHT WAY IF NOT 64
     37          LEAVE      3,1            COMPLETE SERVICE AND LEAVE EAST DOCKS 65
     38          TERMINATE                                                     66
     39   RTWAY  GATE LR    1              BLOCK IF DOOR IN USE                67
     40          LEAVE      3,1            COMPLETE SERVICE AND LEAVE EAST DOCKS 68
     41          TERMINATE                                                     69
     42   SVR2   GATE SNF   2              BLOCK IF WEST DOCKS FULL            70
     43          GATE LR    1                                                  71
                 ***************************************************          72
                 *       NOTE THAT SERVICE TIME IN THIS MODEL INCLUDES  *     73
                 *       THE TIME IN THE QUEUE FOR DEPARTURE FROM ALLEY *     74
                 ***************************************************          75
     44          ENTER      2,1            OCCUPY 1 SPACE AT LOADING DOCK      76
     45          LOGIC R    13             CLEAR SPACE 13                      77
     46          DEPART     1,1            SERVICE COMMENCED                   78
     47          ADVANCE    FN5                                                79
     48          GATE LR    1                                                  80
     49          LEAVE      2,1            COMPLETE SERVICE AND LEAVE WEST DOCKS 81
     50          TERMINATE                                                     82
     51          GENERATE   36000                                              83
     52          LOGIC S    7                                                  84
     53          TEST E     Q1,0                                               85
     54          TEST E     F1,0                                               86
     55          TEST E     S2,0                                               87
     56          TEST E     S3,0                                               88
     57          TERMINATE  1                                                  89
   2      2      STORAGE    2                                                  90
   3      3      STORAGE    2                                                  91
                 START      1                                                  92
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RELATIVE CLOCK 50858 ABSOLUTE CLOCK 50858

BLOCK COUNTS

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
1	0	68	11	0	23	21	0	23	SVR3	0	45	41	0	19
2	0	68	12	0	23	SVR23	0	45	32	0	21	SVR2	0	24
DEC1	0	68	13	0	23	23	0	45	33	0	21	43	0	24
SVR1	0	23	14	0	23	24	0	45	34	0	21	44	0	24
5	0	23	15	0	23	25	0	45	35	0	21	45	0	24
6	0	23	16	0	23	26	0	45	WRWAY	0	21	46	0	24
7	0	23	17	0	23	27	0	45	37	0	2	47	0	24
8	0	23	18	0	23	28	0	45	38	0	2	48	0	24
9	0	23	19	0	23	29	0	45	RTWAY	0	19	49	0	24
10	0	23	20	0	23	30	0	45	40	0	19	50	0	24

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        BLOCK                                                                                  CARD
        NUMBER  *LOC  OPERATION  A,B,C,D,E,F,G,H,I,J         COMMENTS                        NUMBER
                      RMULT      ,975321,420257,320531,111017                                     1
                      SIMULATE                                                                    2
                *     STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 3, CALHOUN                      3
    1           1     FUNCTION   C1,D11                                                           4
    1           3600,225/7200,300/10800,720/14400,514/18000,720/21900,600                         5
    1           25200,1800/28800,277/32400,1800/36000,60000/39600,60000                           6
                *     EXPONENTIAL INTERARRIVAL TIMES                                              7
    2           2     FUNCTION   RN2,C24                                                          8
    2           0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                          9
    2           0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                          10
    2           0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                          11
    2           0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0                       12
                *     GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES                         13
    4           4     FUNCTION   RN3,C24                                                         14
    4           0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                           15
    4           0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                  16
    4           0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                 17
    4           0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800               18
                *     SERVICE TIMES FOR SRV2                                                     19
    5           5     FUNCTION   RN4,C24                                                         20
    5           0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                           21
    5           0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                  22
    5           0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                 23
    5           0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800               24
            1         GENERATE   FN1,FN2,1                                                       25
            2         GATE LR    7                                                               26
            3   DEC1  TRANSFER   .3,SVR2,SVR1                                                    27
            4   SVR1  QUEUE      1,1             QUEUE FOR ENTRY TO ALLEY                        28
            5         GATE LR    1               BLOCK IF LOACING DOOR IN USE                    29
            6         LOGIC S    1               OCCUPY SPACE AT LOADING DOOR                    30
            7         SEIZE      1                                                               31
            8         DEPART     1,1             SERVICE COMMENCED                               32
            9         ADVANCE    FN4                                                             33
           10         RELEASE    1               SERVICE COMPLETED                               34
           11         LOGIC R    1               CLEAR SPACE 1                                   35
           12         TERMINATE                                                                  36
           13   SVR2  QUEUE      1,1             QUEUE FOR ENTRY TO ALLEY                        37
           14         GATE LR    1                                                               38
           15         ENTER      2,1             OCCUPY 1 SPACE AT WEST DOCKS                    39
           16         DEPART     1,1                                                             40
           17         ADVANCE    FN5                                                             41
           18         LEAVE      2,1                                                             42
           19         QUEUE      2,1                                                             43
           20         GATE LR    1                                                               44
           21         DEPART     2,1                                                             45
           22         TERMINATE                                                                  46
           23         GENERATE   36000                                                           47
           24         LOGIC S    7                                                               48
           25         TEST E     Q1,0                                                            49
           26         TEST E     F1,0                                                            50
           27         TEST E     S2,0                                                            51
           28         TEST E     Q2,0                                                            52
           29         TERMINATE  1                                                               53
    2           2     STORAGE    4 DOCK POSTICONS AVAILABLE                                      54
                      START      1                                                               55
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BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J        COMMENTS
               RMULT      ,975321,420257,320531,111017
               SIMULATE
        *      STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 3, CALHOUN
1       1      FUNCTION   C1,D11
1       3600,225/7200,300/10800,720/14400,514/18000,720/21900,600
1       25200,1800/28800,277/32400,1800/36000,60000/39600,60000
        *      EXPONENTIAL INTERARRIVAL TIMES
2       2      FUNCTION   RN2,C24
2       0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69
2       0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12
2       0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5
2       0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0
        *      GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES
4       4      FUNCTION   RN3,C24
4       0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122
4       0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000
4       0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112
4       0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800
        *      SERVICE TIMES FOR SRV2
5       5      FUNCTION   RN4,C24
5       0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122
5       0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000
5       0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112
5       0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800
    1          GENERATE   FN1,FN2,1
    2          GATE LR    7
    3   DEC1   TRANSFER   .2,SVR2,SVR1
    4   SVR1   QUEUE      1,1           QUEUE FOR ENTRY TO ALLEY
    5          GATE LR    1             BLOCK IF LOADING DOOR IN USE
    6          LOGIC S    1             OCCUPY SPACE AT LOADING DOOR
    7          SEIZE      1
    8          DEPART     1,1           SERVICE COMMENCED
    9          ADVANCE    FN4
   10          RELEASE    1             SERVICE COMPLETED
   11          QUEUE      3,1           QUEUE FOR DEPARTURE FROM STATE END
   12          GATE LR    11
   13          LOGIC S    11
   14          LOGIC R    1
   15          GATE LR    12
   16          LOGIC S    12
   17          LOGIC R    11
   18          GATE LR    13
   19          LOGIC S    13
   20          LOGIC R    12
   21          GATE LR    4
   22          LOGIC R    13
   23          DEPART     3,1
   24          TERMINATE
   25   SVR2   QUEUE      1,1           QUEUE FOR ENTRY TO ALLEY
   26          GATE LR    1
   27          ENTER      2,1           OCCUPY 1 SPACE AT WEST DOCKS
   28          DEPART     1,1
   29          ADVANCE    FN5
   30          LEAVE      2,1
   31          QUEUE      2,1
```

BLOCK NUMBER	*LOC	OPERATION	A,B,C,D,E,F,G,H,I,J	COMMENTS	CARD NUMBER
32		GATE LR	1		56
33		DEPART	2,1		57
34		TERMINATE			58
	*	TIME RESTRICTIONS FOR ALLEY ENTRANCE OR EXIT			59
	*	LS SET = CLOSED, LS RESET = OPEN			60
35		GENERATE	1 0800		61
36		GATE LR	41		62
37		LOGIC S	41		63
38		LOGIC S	4		64
39		ADVANCE	5400 0930		65
40		LOGIC R	4		66
41		ADVANCE	7200		67
42		LOGIC S	4		68
43		ADVANCE	7200		69
44		LOGIC R	4		70
45		ADVANCE	7200		71
46		LOGIC S	4		72
47		ADVANCE	7200		73
48		LOGIC R	4		74
49		TERMINATE			75
50		GENERATE	36000		76
51		LOGIC S	7		77
52		TEST E	Q1,0		78
53		TEST E	F1,0		79
54		TEST E	S2,0		80
55		TEST E	Q2,0		81
56		TEST E	Q3,0		82
57		TERMINATE	1		83
2	2	STORAGE	4 DOCK POSTICONS AVAILABLE		84
10	10	QTABLE	1,0,300,75		85
20	20	QTABLE	2,0,300,75		86
30	30	QTABLE	3,0,120,75		87
		START	1		88

RELATIVE CLOCK 40344 ABSOLUTE CLOCK 40344

BLOCK COUNTS

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
1	1	69	11	0	16	21	0	16	31	0	53	41	0	1
2	0	69	12	0	16	22	0	16	32	0	53	42	0	1
DEC1	0	69	13	0	16	23	0	16	33	0	53	43	0	1
SVR1	0	16	14	0	16	24	0	16	34	0	53	44	0	1
5	0	16	15	0	16	SVR2	0	53	35	1	1	45	0	1
6	0	16	16	0	16	26	0	53	36	0	1	46	0	1
7	0	16	17	0	16	27	0	53	37	0	1	47	0	1
8	0	16	18	0	16	28	0	53	38	0	1	48	0	1
9	0	16	19	0	16	29	0	53	39	0	1	49	0	1
10	0	16	20	0	16	30	0	53	40	0	1	50	0	1

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           BLOCK                                                                                          CARD
           NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J       COMMENTS                                  NUMBER
                          PMULT      ,123579,420257,320531,111017                                            1
                          SIMULATE                                                                           2
                    *     STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 5, MARBLE                              3
     1              1     FUNCTION   C1,D11                                                                  4
     1              3600,514/7200,360/10800,240/14400,300/18000,400/21600,300                                5
     1              25200,1200/28800,720/32400,327/36000,1200/39600,60000                                    6
                    *     EXPONENTIAL INTERARRIVAL TIMES                                                     7
     2              2     FUNCTION   RN2,C24                                                                 8
     2              0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                                 9
     2              0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                                 10
     2              0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                                 11
     2              0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0                              12
                    *     GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES                                13
     4              4     FUNCTION   RN3,C24                                                                14
     4              0.0,0.0/0.323,120/0.1,348/0.202,606/0.3,852/0.401,1122                                  15
     4              0.501,1422/0.638,1920/0.701,2202/0.738,2430/0.8,2784/0.828,3000                         16
     4              0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112                        17
     4              0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800                      18
              1           GENERATE   FN1,FN2,1                                                              19
              2           GATE LR    1                                                                      20
              3           QUEUE      1,1                                                                    21
              4           ENTER      1,1                                                                    22
              5           DEPART     1,1                                                                    23
              6           ADVANCE    FN4                                                                    24
              7           LEAVE      1,1                                                                    25
              8           TERMINATE                                                                         26
              9           GENERATE   36000                                                                  27
             10           LOGIC S    1                                                                      28
             11           TEST E     Q1,0                                                                   29
             12           TEST E     S1,0                                                                   30
             13           TERMINATE  1                                                                      31
     1              1     STORAGE    5 DOCKS AVAILABLE                                                      32
     1              1     QTABLE     1,0,120,75                                                             33
                          START      1                                                                      34


RELATIVE CLOCK       42726   ABSOLUTE CLOCK       42726
BLOCK COUNTS
BLOCK     CURRENT   TOTAL   BLOCK    CURRENT   TOTAL   BLOCK     CURRENT   TOTAL   BLOCK     CURRENT   TOTAL   BLOCK     CURRENT   TOTAL
   1         1       108      11        0        1
   2         0       108      12        0        1
   3         0       108      13        0        1
   4         0       108
   5         0       108
   6         0       108
   7         0       108
   8         0       108
   9         0         1
  10         0         1
```

```
           BLOCK                                                                                CARD
           NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J        COMMENTS                        NUMBER
                          RMULT      ,123579,420257,320531,111017                                  1
                          SIMULATE                                                                 2
                   *      STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 5, MARBLE                    3
       1           1      FUNCTION   C1,D11                                                        4
       1           3600,514/7200,360/10800,240/14400,300/18000,400/21600,300                       5
       1           25200,1200/28800,720/32400,327/36000,1200/39600,60000                           6
                   *      EXPONENTIAL INTEFARRIVAL TIMES                                           7
       2           2      FUNCTION   RN2,C24                                                       8
       2           0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                        9
       2           0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                        10
       2           0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                        11
       2           0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0                     12
                   *      GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES                      13
       4           4      FUNCTION   RN3,C24                                                      14
       4           0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                         15
       4           0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000                16
       4           0.867,3360/0.906,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112               17
       4           0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800             18
              1           GENERATE   FN1,FN2,1                                                    19
              2           GATE LR    1                                                            20
              3           QUEUE      1,1                                                          21
              4           GATE LR    4              BLOCK ENTRY IF TIME RESTRICTION IS IN EFFECT  22
              5           ENTER      1,1                                                          23
              6           DEPART     1,1                                                          24
              7           ADVANCE    FN4                                                          25
              8           LEAVE      1,1                                                          26
              9           TERMINATE                                                               27
                   *      TIME RESTRICTIONS FOR ALLEY ENTRANCE OR EXIT                            28
                   *      LS SET = CLOSED, LS RESET = OPEN                                        29
             10           GENERATE   1              0800                                          30
             11           GATE LR    41                                                           31
             12           LOGIC S    41                                                           32
             13           LOGIC S    4                                                            33
             14           ADVANCE    5400           0930                                          34
             15           LOGIC R    4                                                            35
             16           ADVANCE    7200                                                         36
             17           LOGIC S    4                                                            37
             18           ADVANCE    7200                                                         38
             19           LOGIC R    4                                                            39
             20           ADVANCE    7200                                                         40
             21           LOGIC S    4                                                            41
             22           ADVANCE    7200                                                         42
             23           LOGIC R    4                                                            43
             24           TERMINATE                                                               44
             25           GENERATE   36000                                                        45
             26           LOGIC S    1                                                            46
             27           TEST E     Q1,0                                                         47
             28           TEST E     S1,0                                                         48
             29           TERMINATE  1                                                            49
       1           1      STORAGE    5 DOCKS AVAILABLE                                            50
       1           1      QTABLE     1,0,120,75                                                   51
                          START      1                                                            52
```

```
        BLOCK                                                                       CARD
        NUMBER  *LOC  OPERATION  A,B,C,D,E,F,G,H,I,J       COMMENTS                 NUMBER
                      RMULT      .123579,420257,320531,111017                          1
                      SIMULATE                                                         2
                *     STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 6, QUINCY            3
     1          1     FUNCTION   C1,D11                                                4
     1          3600,400/7200,240/10800,277/14400,900/18000,514/21600,1800             5
     1          25200,450/28800,1800/32400,60000/36000,60000/39600,60000               6
                *     EXPONENTIAL INTERARRIVAL TIMES                                   7
     2          2     FUNCTION   RN2,C24                                               8
     2          0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69               9
     2          0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12               10
     2          0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5               11
     2          0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0            12
                *     GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES              13
     4          4     FUNCTION   RN3,C24                                              14
     4          0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                15
     4          0.501,1422/0.639,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000       16
     4          0.867,3360/0.904,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112      17
     4          0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800    18
          1           GENERATE   FN1,FN2,1                                            19
          2           GATE LR    1                                                    20
          3           QUEUE      1,1                                                  21
          4           ENTER      1,1                                                  22
          5           DEPART     1,1                                                  23
          6           ADVANCE    FN4                                                  24
          7           LEAVE      1,1                                                  25
          8           TERMINATE                                                       26
          9           GENERATE   36000                                                27
         10           LOGIC S    1                                                    28
         11           TEST E     Q1,0                                                 29
         12           TEST E     S1,0                                                 30
         13           TERMINATE  1                                                    31
     1          1     STORAGE    7 LOADING ZONES AVAILABLE                            32
     1          1     QTABLE     1,0,120,75                                           33
                      START      1                                                    34
```

```
RELATIVE CLOCK      36000   ABSOLUTE CLOCK      36000
BLOCK COUNTS
BLOCK  CURRENT  TOTAL  BLOCK  CURRENT  TOTAL  BLOCK  CURRENT  TOTAL  BLOCK  CURRENT  TOTAL  BLOCK  CURRENT  TOTAL
   1       0      81     11      0       1
   2       0      81     12      0       1
   3       0      81     13      0       1
   4       0      81
   5       1      81
   6       0      81
   7       0      81
   8       0      81
   9       0       1
  10       0       1
```

```
      BLOCK                                                                           CARD
      NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G,H,I,J       COMMENTS                    NUMBER
                     RMULT      .123579,420257,320531,111017                            1
                     SIMULATE                                                           2
               *     STEP FUNCTION FOR MEAN I/A TIMES, ALLEY NO. 6, QUINCY              3
   1           1     FUNCTION   C1,D11                                                  4
   1          3600,400/7200,240/10800,277/14400,900/18000,514/21600,1800                5
   1          25200,450/28800,1800/32400,60000/36000,60000/39600,60000                  6
               *     EXPONENTIAL INTERARRIVAL TIMES                                     7
   2           2     FUNCTION   RN2,C24                                                 8
   2          0.0,0.0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69                  9
   2          0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12                  10
   2          0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5                  11
   2          0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0               12
               *     GAMMA SERVICE TIMES, A=1.5, B=20, ALLEY DELIVERIES                13
   4           4     FUNCTION   RN3,C24                                                14
   4          0.0,0.0/0.023,120/0.1,348/0.202,606/0.3,852/0.401,1122                   15
   4          0.501,1422/0.638,1920/0.701,2202/0.738,2400/0.8,2784/0.828,3000          16
   4          0.867,3360/0.966,3840/0.934,4320/0.95,4704/0.954,4800/0.963,5112         17
   4          0.971,5418/0.981,6006/0.985,6288/0.987,6474/0.9882,6600/0.999,7800       18
         1           GENERATE   FN1,FN2,1                                              19
         2           GATE LR    1                                                      20
         3           QUEUE      1,1                                                    21
         4           GATE LR    4          BLOCK EXIT IF TIME RESTRICTION IN EFFECT    22
         5           ENTER      1,1                                                    23
         6           DEPART     1,1                                                    24
         7           ADVANCE    FN4                                                    25
         8           LEAVE      1,1                                                    26
         9           QUEUE      2,1        QUEUE FOR DEPARTURE FROM ALLEY              27
        10           GATE LR    4          BLOCK EXIT IF TIME RESTRICTION IN EFFECT    28
        11           DEPART     2,1        LEAVE ALLEY                                 29
        12           TERMINATE                                                         30
               *     TIME RESTRICTIONS FOR ALLEY ENTRANCE OR EXIT                      31
               *     LS SET = CLOSED, LS RESET = OPEN                                  32
        13           GENERATE   1          0800                                        33
        14           GATE LR    41                                                     34
        15           LOGIC S    41                                                     35
        16           LOGIC S    4                                                      36
        17           ADVANCE    5400       0930                                        37
        18           LOGIC R    4                                                      38
        19           ADVANCE    7200                                                   39
        20           LOGIC S    4                                                      40
        21           ADVANCE    7200                                                   41
        22           LOGIC R    4                                                      42
        23           ADVANCE    7200                                                   43
        24           LOGIC S    4                                                      44
        25           ADVANCE    7200                                                   45
        26           LOGIC R    4                                                      46
        27           TERMINATE                                                         47
        28           GENERATE   36000                                                  48
        29           LOGIC S    1                                                      49
        30           TEST E     Q1,0                                                   50
        31           TEST E     S1,0                                                   51
        32           TEST E     Q2,0                                                   52
        33           TERMINATE  1                                                      53
   1           1     STORAGE    7 LOADING ZONES AVAILABLE                              54
                     START      1                                                      55
```

```
                  PROGRAM LAURIE(INPUT,OUTPUT,TAPE1=INPUT,TAPE2=OUTPUT)
       3          DELTAX=0.1
       5          DO 25 K=1,3
       6          X=0.1
       7          F=0.0
      10          READ(1,10) A,B,G
      22       10 FORMAT(3F10.0)
      22          DO 25 I=1,110
      24          F=F+DELTAX*(X**(A-1.0)*EXP(-X/B)/(G*B**A))
      47          IF(I.LE.800) GO TO 15
      52          WRITE(2,20) A,B,G,X,F
      70       15 X=X+0.1
      72       20 FORMAT(1X,5F10.5)
      72       25 CONTINUE
      76          STOP
     100          END
  LAURIE
```

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VITA

John Vincent Madden ("Jack") was born on January 19, 1951 in Boston, Massachusetts. He received a B.S. in Industrial Engineering from Northwestern University in June 1973, and was a Distinguished Military Graduate. Under an Army fellowship, he has completed the requirements for a Master of Science in Transportation at Northwestern University in Evanston, Illinois.

Immediately prior to the work on this thesis, he participated in a research project for the Chicago and North Western Railroad. Jack is a member of Alpha Pi Mu, and is on active duty as a First Lieutenant in the U.S. Army Transportation Corps.